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Analyzing The Potential Of Bioelectrical Impedance Analysis In Identifying The Effects Of Freezing In Atlantic Sea Scallop Products (Placopecten Magellanicus)

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Analyzing the potential of bioelectrical impedance analysis in identifying the effects of freezing in Atlantic sea scallop products (*Placopecten magellanicus*)

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Table of Contents

Abstract

The sensitivity of bioelectrical impedance analysis (BIA) was investigated to assess the potential of identifying the effects of freezing in market-ready Atlantic sea scallops (*Placopecten magellanicus*). Measurements of resistance (R) and reactance (X_c) were recorded using a Certified Quality Reader (CQR) (Certified Quality Food Inc., Clinton Township, MI 48035) BIA device at 50kHz. Prior to investigating the effects of freezing on BIA measurements a standard operating procedure (SOP) was established to limit sources of error. BIA measurements were used in establishing an SOP which focused upon the preparation of samples through blot drying, as well as, proper orientation of scallops in relation to BIA measurement tools. Once completed, the effects of freezing were investigated by comparing BIA measurements of samples when fresh and after two freezing cycles. Additionally, measurements were taken from samples that were previously frozen using individual quick freeze (IQF) as an additional source of frozen tissue. BIA measurements were capable of identifying the effects of freezing upon scallop tissue when subjected to freezing; therefore, BIA has the potential to be an accurate and precise tool in identifying previously frozen scallop products, which will allow scallop marketing companies to rapidly inform retailers as to the added value of their products.

1.0 Background

Seafood is one of the most valuable internationally traded food commodities representing 10% of all food trade (by value) (World Bank, 2013; Asche, 2014). Seafood trade plays an important role in the survival of many communities around the world by providing a valuable source of food and income through local and international trade (Cox, 2013). In 2018, United States domestic seafood products totaled to nearly $5.6 billion dollars for which fish and shellfish represented 87.8% and 11.8% of the total volume landed, respectively. Shellfish represented the largest share of the total value of landings at 54.3% in comparison to fish at 45.2%. The differences in volume and value shares illustrate the economic significance of U.S. shellfish products. In particular, those harvested from New England such as American lobsters and Atlantic sea scallops (Appendix 1) (NMFS, 2020).

Seafood products, including shellfish, are highly nutritious and a beneficial addition to human diets, as they contain essential amino acid and minerals, highly digestible proteins, and a high content of polyunsaturated fatty acids (Manthey-Karl *et al*. 2015). However, seafood products are highly perishable when handled improperly post-harvest it compromises not only their nutritional, but economic value as well. In order to maintain their highest nutritional and economic values, quality and condition must be maintained from harvest to the end consumer (Cox, 2013).

Seafood products are perishable because immediately upon harvest they are susceptible to biological and physiochemical changes that result in the degradation of quality and condition. Degradation and rates at which spoilage occurs in seafood products are variable due to natural processes and handling procedures. Factors that contribute to spoilage post-harvest include interactions between products and handling equipment, interactions between products and surrounding environments, and inherent species-specific biochemical, physiochemical, and microbiological processes, and environmental conditions (Cox, 2013; Opara *et al.*, 2007).

When such aforementioned factors are not controlled the quality and condition (i.e. freshness) of seafood products diminish. Lack of control ultimately limits usability and negatively effects value. Usability of seafood products depends greatly upon the quality and condition of the product. Products of higher quality and freshness have higher values and used mainly for direct consumption with limited processing. Products of lower quality and freshness are processed for human consumption (i.e. surimi), used for non-human consumption (i.e. fishmeals or fertilizers), or discarded (Yuan et. al., 2018). Therefore, it is important for the seafood industry to utilize rapid, efficient, and accurate methods of assessing quality and condition to properly value products, as well as, assure the safety of consumers.

A challenge the seafood industry often faces in the delivery of high-quality products is distance between target markets and locations where harvesting and processing occur (Opara *et al*., 2007). Prior to innovations in logistics and transportation the sale of fresh seafood was limited to markets in close proximity to harvest locations. Developments within seafood supply chains such as efficient product preservation, lower transportation costs and shorter transport durations have made a greater number of affordable options available to consumers through international markets (Asche & Smith, 2010). In international markets, seafood products to follow a series of handling and processing operations from the point of harvest until products have reached final consumers (Opara *et al.*, 2007).

To maintain quality during transport, processing, and storage, seafood products are often frozen as an efficient means of extending shelf-life (Fernández-Segovia *et al*., 2012). When seafood products are frozen, injury to tissues occur in the form of protein denaturation and lipid oxidation. Sensory and nutritional qualities of seafood products are affected when improper handling and freezing processes are utilized. If proper handling and freezing processes are utilized, there can be limited effects upon sensory qualities of products making it difficult to identify previously frozen products from fresh ones using sensory observations (Fernández-Segovia *et al*., 2012; Vidaček *et al*. 2008) Having the ability to rapidly identify previously frozen product would be of immense value to the seafood industry by improving quality assurance and product marketability.

Typically, consumers prefer fresh seafood products over frozen ones despite fresh products receiving higher prices (Fernández-Segovia *et al*., 2012). Increased processing can incentivize sellers to mislabel previously frozen products as fresh. This fraudulent practice of selling thawed-frozen products as fresh is of great concern for retailers and consumers, particularly when traceability of products is inadequate (Warner *et* al., 2013). The U.S. Food & Drug Administration (FDA) under the Fair Packaging and Labeling Act requires a statement of identity to be prominently displayed on packaging requiring labelling such as fresh, frozen, pasteurized, canned, or dried, which helps in dictating to consumers as to how products should be properly stored prior to consumption (CPG Sec 562.450) (FDA, 1980). Mislabeling products leads to improper storage and handling which can have serious consequences on human health with respect to contamination by toxins associated with degradation as well as concerns associated with preservatives and additives (Warner *et al*., 2013).

The use of chemical preservatives and additives, such as polyphosphates, have historically been widely used and accepted in fresh and frozen seafood products. However, consumers have become increasingly interested in the composition of foods they eat leading to consumer demands and regulations requiring that products which have been treated to be labeled as such. To circumvent labeling requirements and promote the sale of treated products, the use of citric acid and bicarbonates have been introduced which can be exceedingly difficult to detect (Manthey-Karl *et al*., 2015).

Polyphosphates, citric acid, and bicarbonates are often used to maintain or add additional moisture to seafood products. There is increasing concern over the excessive use these chemicals and the aspect of “added water” retention as it can lead to unfair trade practices (Upton, 2015). By adding water to seafood products, the weight and size of the products increase allowing for greater economic gain for sellers at low costs. This fraud can go undetected by purchasers and consumers who inevitably pay for added water instead of meat. By altering the natural ratio of meat to moisture the quality of seafood products decreases, and end users such as chefs can readily observe the manipulated product when prepared.

1.1 Assessing Quality in Seafood

Quality in seafood products is a widely used term that can often be difficult to define as it varies objectively between products as well as subjectively in personal interpretations. Generally, it is agreed that freshness is the most important aspect of seafood quality. Freshness is related directly to sensory perceptions of consumers through appearance, texture, smell, and taste. However, describing quality based upon freshness can be difficult and complicated to do particularly when traceability in seafood supply chains is limited (Hassoun & Karoui, 2017).

Current methods of distinguishing quality in fresh and frozen seafood products rely upon different analytical methods based upon physical, chemical, and sensory measurements such as the Quality Index Method (QIM) (Huss, 1995). QIM is reliant upon the objective sensory evaluation of specially trained personnel who interpret qualities of seafood products based upon appearances, odors, flavors, and textures based upon species-specific models. Products are often graded using a scoring system, which can be ascending or descending depending on country, region, or preference of the assessor. This method entails three separate processes which can be vary from assessor to assessor. First, a stimulus is detected by sensory organs, then interpreted and evaluated through mental processes, and lastly, responses to stimuli are made by the assessor. Interpretations and evaluations can differ from person to person, as well as, change within individuals over time. In addition, there can be inherent and unintended subjectivity by assessors using QIM, such as an aversion to certain products (Huss,1995).

Hazardous Analysis and Critical Control Points (HACCP) is used in assessing quality of seafood products. HACCP addresses and assures product safety through control of food borne safety hazards such as pathogens, contamination, decomposition, pesticides, industrial chemicals, and marine biotoxins (Kvenberg & Schwalm, 2000). However, QIM and HAACP can be limited in capability and application as they can be exceedingly complex, tedious, and expensive. They require skillfully trained personnel to carry out time-consuming investigations that can make it difficult to evaluate the condition of products rapidly (Fernández-Segovia *et al*., 2012; Yuan *et al*. 2018). Therefore, as seafood trade continues to grow worldwide there is an increasing importance to devise methods in assessing product quality in more rapid and cost-effective ways that limit subjectivity, complexity, and cost (Cox, 2013).

Current quantitative methods of quality and freshness assessments are often destructive. These methods require samples to be macerated, treated with acids and/or other compounds before being vaporized using distillation (Altissimi *et al.,* 2018). Such methods limit the opportunities for subsequent testing of individual samples to investigate contamination or other physical changes (Hassoun & Karoui, 2017).

Total volatile basic amines (TVB) is the most common method for quantitative measurement of quality in seafood products. TVB is used to measure the presence and amounts of volatile compounds that are produced as seafoods degrade (mostly done for fish), such as those produced by bacteria and breakdown of enzymes. Although widely used and capable of measuring a wide variety of compounds, TVB measurements can only prove valuable after decomposition or extended storage have taken place (Huss, 1995).

Additional physiochemical measurements of freshness in seafood products include those that measure lipid oxidation, such as thiobarbituric acid reactive substances (TBARS) and peroxide values (PVs). Seafoods contain high levels of polyunsaturated fatty acids which make them highly susceptible to oxidation reactions (Hassoun & Karoui, 2017). The measurement of adenosine triphosphate (ATP) concentrations in seafoods has also been used as an indicator of freshness. ATP is an important compound to living tissue as a source of energy used in a variety of cellular processes. As muscular tissue degrades after death, ATP metabolizes into several other compounds that can be indicative of varying levels of spoilage and degradation (Hassoun & Karoui, 2017).

Physiochemical methods such as TVB, TBARS, PVs, and ATP concentrations require the use of high-level laboratories and trained personnel to extract compounds which can be considerably expensive, time consuming, and difficult to reproduce (Hassoun & Karoui, 2017). Additionally, a lack of knowledge concerning acceptable limits of various compounds for different species limits the efficacy of chemical testing throughout seafood value chains (Altissimi *et al.,*2018). The development of alternative methods of assessing condition, quality, and decomposition in seafood products rapidly, cheaply, and with limited effects upon samples would be very beneficial for industry and consumers (Fernández-Segovia *et al*., 2012).

Non-destructive methods of assessing condition and quality of biological tissues have been developed that can potentially be utilized in the seafood industry. These methods include conditional analysis, visible/near-infrared fluorescent spectroscopy, total body electric conductivity (TOBEC), nuclear magnetic resonance (NMR), computerized tomography (CT) and bioelectrical impedance analysis (BIA) (Cox & Hartman, 2005; Hassoun & Karoui, 2017; Duncan *et al*., 2007; He *et al*., 2014). Due to limitations including costs of equipment and operation, limited transportability, and inefficiencies in producing accurate measurements, most of these methods have limited commercial application in the seafood industry (Duncan *et al*., 2007; He *et al*., 2014). However, in recent years bioelectric impedance analysis (BIA) has become the focus of studies in fish and seafood products. BIA devices are easily transported and can produce several simultaneous measurements pertaining to quality rapidly, cheaply, and with very little training (Cox *et al*., 2011).

1.2 Bioelectric Impedance Analysis (BIA)

BIA is based upon the understanding that all biological tissues are composed of cells which develop in a three-dimensional array containing intracellular fluids (ICF) and cell membranes (CM) suspended in extracellular fluids (ECF). ICF, CM, and ECF are composed of different materials, each of which have distinguishable bioelectrical properties and behaviors when subjected to an alternating current (Bera, 2014, Lukaski, 2013). Under alternating electrical excitation, an electrical current will flow through the length of the sample with a measurable amount of opposition or impedance (Z) (Figure 1). The amount of opposition or bioelectrical impedance is then used in approximations of tissue condition and physiology (Bera, 2014).

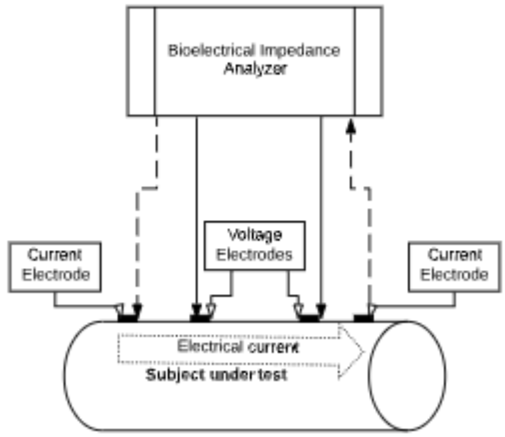

Figure 1: General depiction a bioelectrical impedance analysis (BIA) device with a four-electrode array. Electrical current is emitted into one end of the sample from current electrode attached to the BIA device. The current flows through the length of the sample and returns to the BIA device through a current electrode at the opposing end. Changes in electrical currents due to differences in biological tissues are measured by the voltage electrodes between the current electrodes (Adapted from Bera, 2014).

Impedance (Z) or the effective opposition to the flow of an applied electric current is dependent upon the frequency of applied alternating current and the distribution of conductive and non-conductive materials within a given sample. Z is calculated using the sum of two measurable oppositions to the flow of electricity, resistance (R) and reactance (X_c) using the equation:

$$Z^2 = R^2 + {X_c}^2 \quad (1)$$

Resistance (R) is the measurable opposition that non-conductive material located in interstitial spaces and extracellular fluid has upon the flow of electrical current as it passes through a sample. When a sample has a high amount of extracellular fluid containing electrolytic material and low lipid/fat content, R values will be low due to increased interstitial volume. Conversely, when a tissue sample has lower levels of extracellular fluid and high levels of lipid/fat content R values will be high due to decreased interstitial volume. Therefore, R measurements are often used in predictive equations relating to lipid/fat content (Fernández-Segovia *et al*., 2012).

Reactance (X_c) is the opposition to applied current caused by the capacitance of non-conductive materials. Capacitive materials, such as the insulative lipid bilayer of cell membranes, will briefly hold a charge before releasing the charge. The actions of capacitive material will cause a phase shift or a measurable delay in the flow of current. Therefore, X_c is indicative of cell volume which is proportionate to the volume of intracellular fluid and the health of cells. Healthy cells will possess higher amounts of intracellular fluids than unhealthy or degrading cells. Healthy cells will exhibit higher X_c measures due to larger cell volumes. Conversely, lower X_c values are indicative of cells of lower volumes due to low volumes of intracellular fluid. X_c measurements are often used in predictive equations to estimate cell volumes as they relate to the overall health of cells within a sample. Therefore, BIA can be used to assess altering states of health and physical condition of biological tissues (Chumlea & Guo, 1997; Pothoven *et* al., 2008; Lukaski, 2013; Bera, 2014,].

BIA was first introduced into the human health field as a non-invasive method of assessing water and electrolyte contents and their relationships to organ functions, metabolic rates, hormone activities, and blood flows in biological tissues (Chumlea & Guo, 1997). These investigations have allowed for developments such as electrocardiography (ECG) and electroencephalography (EEG) (Chumlea & Guo, 1997; Bera, 2014; Khalil et al., 2014). Further investigations have allowed for the development of different methods of BIA including Single Frequency Bioelectrical Impedance Analysis (SF-BIA), Multiple Frequency Bioelectrical Impedance Analysis (MF-BIA), and Bioelectrical Impedance Spectroscopy (BIS) (Khalil et al., 2014).

Single Frequency Bioelectrical Impedance Analysis (SF-BIA) is the most common among the different methods of BIA and uses a single frequency, generally at 50kHz. SF-BIA is based upon the inverse relationship between impedance and total body water (intra- and extracellular fluid) that represents the flows of electrical currents. In comparison to Multiple Frequency Bioelectrical Impedance Analysis (MF-BIA) and Bioelectrical Impedance Analysis (BIS), SF-BIA has been documented as more accurate in detecting the movement of fluids between extracellular fluids (ECF) and intracellular fluids (ICF) which are associated with declining tissue conditions (Khalil et al., 2014).

MF-BIA and BIS are methods which utilize at least more than one frequency. The difference between these methods are that BIS uses a broad band of frequencies to determine resistance at zero frequency (R_0) and resistance at infinity frequency (R_{inf}) whereas MF-BIA uses two or more pre-selected frequencies. Due to the differences in responses by different tissues types the use of multiple frequencies can allow for more precise predictions to be made when multiple tissue types are present within a sample (Bera, 2014; Khalil et al., 2014.)

1.2.1 Bioelectrical Impedance Analysis in Fish and Seafood Products

BIA has been investigated as a useful assessment tool for the physiological properties of living fish for a variety of species with varying levels of success. Successful attempts have allowed for the creation of species-specific BIA models utilizing calibration equations to accurately correlate bioelectrical impedance measurements (BIM) to the outcomes of other proximate analysis methods (Hartman *et al*., 2015). If proper calibration equations are established, BIA can used to provide accurate predictions of proximal and conditional analysis without the need to destroy/sacrifice products (Cox & Hartman, 2005). Thus, BIA models can become a very important and valuable tool to the seafood industry. This is especially so when dealing with high value species such as Atlantic sea scallops or species that are in low abundance, threatened, or endangered (Pothoven et al, 2008, Hartman et al., 2015).

BIA has also shown potential to be used in identifying previously frozen products (Vidaček *et al*. 2008; Fernández-Segovia *et al*., 2012; Cox, 2013; Yuan *et al*. 2018). When subjected to freezing injury tissues experience protein denaturation and lipid oxidation. Injuries cause alterations to tissue structures and functions as cells become dehydrated leading to a loss of cellular membrane integrity. When the integrity of the lipid bilayer of cellular membrane degrades, its' capacitive ability is diminished resulting in lower observed reactance (X_C) values (Cox, 2013). In addition, the loss in cellular integrity causes a decline in the osmotic pressure gradient within cells which limits the amount of material that could permeate into cells. With the loss of this barrier the cells begin to expand as extracellular fluids and macromolecules permeate inward. Influx causes the cells to over expand leading to lysing, ultimately allowing conductive cellular contents to permeate into extracellular spaces. When this occurs the conductivity of extracellular tissue increases which can be observed in declining resistance (R) values. The summation of these effects can be observed in declining values of impedance (Fernández-Segovia *et al*., 2012; Cox, 2013; Yuan *et al*., 2018).

1.3 Atlantic sea scallops (*Placopecten magellanicus*)

Placopecten magellanicus, commonly known as the Atlantic sea scallop or sea scallop, is a species of benthic macroinvertebrate living at depths of 18-110m (Stokesbury *et al.,*2016). The species is endemic to the continental shelf of the northwest Atlantic Ocean from Newfoundland, Canada to Cape Hatteras, North Carolina (NOAA, 2020). Atlantic sea scallops are commercially harvested year-round throughout this range. The largest US Atlantic sea scallop fisheries are located on Georges Bank, the Mid-Atlantic Bight and a small but very valuable inshore fishery in the Gulf of Maine. Canadian offshore fisheries are located on the Eastern Scotian Shelf, as well as, Georges, Browns, German, and St. Pierre Banks with a small inshore fishery in the Bay of Fundy (Stokesbury *et al.,*2016) (Figure 2). Sea scallop products harvested by United States fishermen are known to be a smart seafood choice as the fishery is sustainably managed under stringent regulations (NOAA, 2020). In 2018, 26,263 metric tons (57.9 million pounds) of Atlantic sea scallops were landed by US fishermen accounting for $532.3 million of the $5.6 billion seafood industry in the United States (NMFS, 2020).

Figure 2: Map of Atlantic sea scallop (*Placopecten magellanicus*) distribution. The species is found throughout the continental shelf of the northwestern Atlantic Ocean along the coasts of the United States and Canada (Source: conxemar.com)

There are 44 distinct scallop homeports along the east coast of the United States from North Carolina to Maine with the largest being New Bedford, Massachusetts, Cape May, New Jersey, and Newport News, Virginia (Stokesbury et al. 2016). The port of New Bedford, Massachusetts although being ranked thirteenth in volume at 51,710 metric tons (114 million pounds) was ranked the highest value port in the United States in 2018 at $431 million, largely due to the 18,325 metric tons (40.4 million pounds) of Atlantic sea scallops landed at an average ex-vessel price of $9.20 per pound (NMFS, 2020).

1.4.1. Atlantic sea scallop products

Atlantic sea scallops are one of the numerous species of bivalves harvested along the eastern coast of the United States and Canada. The Atlantic sea scallop fishery of the northwestern Atlantic Ocean has become one of the most prominent fisheries in the world due to its economic value and high demands for scallop products. Scallop meats of larger sizes often receive higher demands and prices. Scallops are sold by count per weight or units per pound in US markets, therefore, distributors and processors will grade products by size prior to packaging. Consumers can identify size of product and number to be expected in packaging using the common labeling system used within the seafood industry (U/10, U/10-20, U/20-30, U/30-40) (FishChoice, 2020).

Most of the sea scallop products that come to markets from US fisheries are harvested during "long haul voyages". "Long haul voyages" are defined as when vessels are at sea for 10 days or less, and in some cases, 12 to 15 days. The remaining sea scallop products brought to market are harvested during "short haul voyages" lasting 1-2 days, often marketed as "day boat scallops". Sea scallops are most often harvested using scallop dredges or trawls. Dredge configurations will vary depending on regulations, vessel size, and region. The most common configuration used by US fishermen is the New-Bedford style dredge and is designed to target adult scallops larger than 100mm shell height (Figure 3). Developments in dredge design over the past decade have focused upon bycatch mitigation, particularly for sea turtles (Stokesbury et al. 2016).

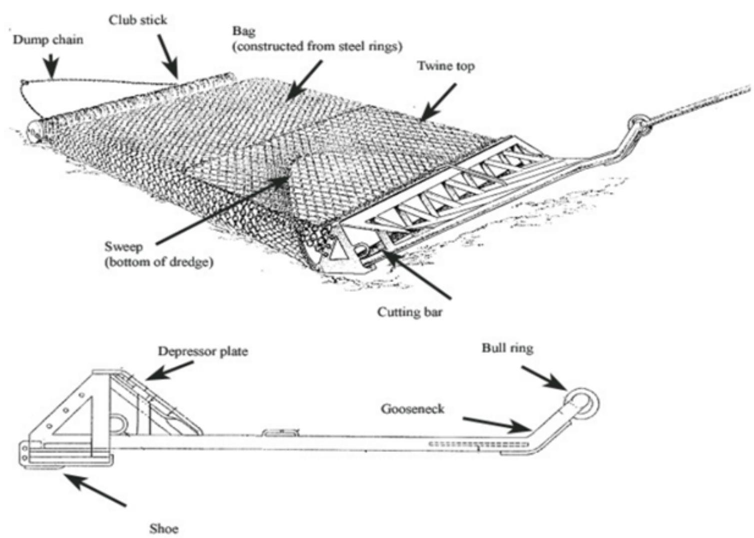

Figure 3: Illustration of a New Bedford style scallop dredge. Style most commonly used by U.S. fishermen to harvest Atlantic sea scallops (*Placopecten magellanicus*) (Source: Smolowitz et al., 2012)

Once harvested each scallop is shucked by hand removing both the shells and organs leaving behind the adductor muscle or scallop meat. Shucked scallop meats are stored on-board in cotton or linen bags and chilled using freshwater ice until landed at port (DuPaul *et al*., 1990). Once landed at port scallop products either brought directly into processing facilities or enter auctions to be purchased by distributors and processors. Purchasers base purchasing decisions upon the quality of product as it relates to date of harvest, coloration, firmness, and lack of parasites or decay (Handy, 2019).

1.4.2 Quality and moisture content in scallop products

Scallops exhibit similar behaviors to other seafood products as upon harvest freshness and quality begin to decline. Rates of decline are dependent upon handling techniques and seasonal variations in respect to inherent biological parameters, water temperatures, and temperatures onboard when scallops are being processed (DuPaul et al., 1996). Therefore, proper onboard handling and processing are integral in maintaining the value and quality of scallop products.

In addition to assessing quality and condition using the Quality Index Method (QIM) and Hazardous Analysis and Critical Control Points (HAACP) there is significant interest within the scallop industry to accurately assess moisture content by weight. Historically, quality in scallop products has been correlated to moisture content as it directly affects the performance of scallop products when prepared for consumption, as well as, nutritional values (Manthey-Karl *et al*., 2015). Studies have found natural moisture contents in fresh scallops is within the range of 75-80% (DuPaul *et al*., 1996; NOAA, 2017).

Prior to harvest, natural moisture contents of scallops are influenced by several biotic factors such as abundance of food, reproductive cycles, and the overall health of the individual scallops. In turn, biotic factors are responsive to abiotic factors including seasonal variations, water depth, and various oceanographic characteristics (Figure 4) (DuPaul *et al*., 1996). Due to the high level of variability in biotic and abiotic influences throughout seasons and regions, natural moistures can be difficult to predict prior to harvest.

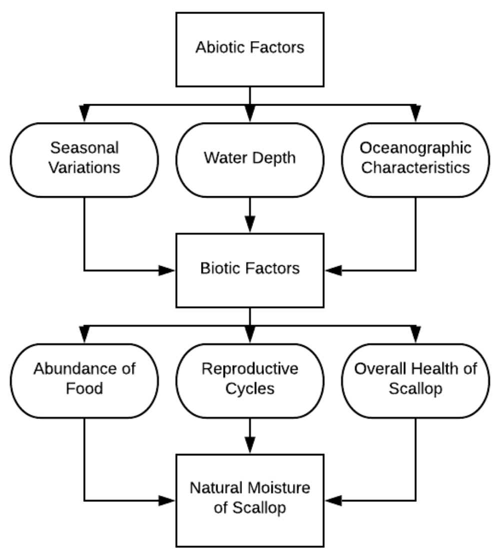

Figure 4: Factors affecting natural moisture in commercially harvested scallops. (Adapted from DuPaul *et al*., 1996)

Moisture content and quality in scallop products are significantly influenced by harvesting methods and post-harvest treatments (Figure 5). However, these influences can be highly predictable (DuPaul *et al*., 1996). Prior to shucking of scallops, improper harvesting and handling methods can induce high levels of stress upon captured scallops. Stress will cause premature and increased deterioration exhibited in higher levels of drip loss, softening of muscle tissue, and rapid onset of rigor mortis (Mitchell, 2017). Once shucked, scallops are maintained in storage holds using freshwater ice to limit degradations. The adductor muscle or meat of a scallop is composed of parallel strands of fibers that are susceptible to water absorption from melting ice through capillary action. Therefore, moisture content will increase dependent upon the duration of contact with melted ice (DuPaul *et al*., 1996).

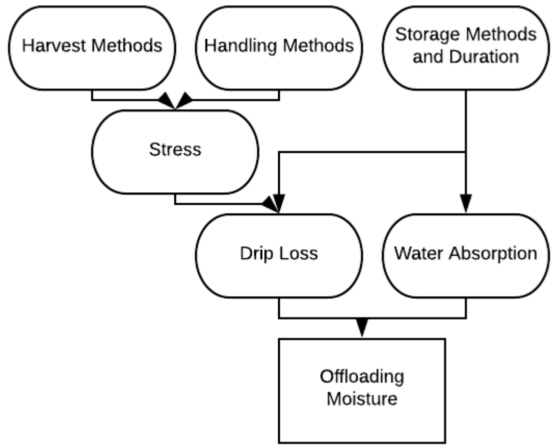

Figure 5: Factors affecting moisture in scallops after capture before being landed onshore.

Scallops will naturally exhibit drip loss after harvest resulting in a declining moisture content. To limit the loss of moisture during processing it is common within the scallop industry to utilize water retaining of additives, such as polyphosphates. Additives are also used to reconstitute products after drip loss has occurred. However, the addition of water to scallop products can cause moisture content and weight of products to become significantly higher than original levels (Manthey-Karl *et al*., 2015).

Prior to 1992, regulations concerning added water and the use of additives in scallop products were limited. On August 31st, 1992, the Food and Drug Administration (FDA) and the Seafood Inspection Program (SIP) came to an interim agreement with the scallop industry creating the "Interim Labeling Policy Establish for Scallops" (NOAA, 2017). The policy addressed consumer concerns of added water and the use of polyphosphates by establishing proper labeling declarations and acceptable moisture content parameters for scallop products. Under the policy scallop products with moisture content exceeding 79.9% were to be labeled as "water added" and must include the degree to which water was added. The policy also stated that scallop products exceeding 84% moisture content were deemed "adulterated" and unfit for consumption, regardless of labeling. Imported scallop products were included in the agreement and were mandated to meet the same requirements as domestic products. The parameters of this agreement proved exceedingly restrictive and confusing for domestic producers, importers, and exporters. Those concerned stated that regulations did not properly account the natural variability in scallops and the differences associated to harvesting and handling practices. However, due to limited data available at the time concerning moisture content in scallops the regulations proved difficult to support or argue (DuPaul *et al*., 1996, NOAA, 2017).

The FDA regulations imposed by the "Interim Labeling Policy Established for Scallops" remained in effect until being rescinded on May 18th, 2004. By rescinding the policy, water percentages used for label declarations are no longer being enforced. However, scallop products that have been treated with additional water are still required to be prominently labeled and all additives included within ingredient statements (NOAA, 2017). Additionally, the market practice of labeling and marketing scallop products as “dry” has become common. This is used to notify consumers that products have not treated chemically or subjected to added water (FishChoice, 2020).

1.4.3 Assessing moisture content in scallop products

To maintain compliance with regulations scallop processors must monitor moisture contents of scallops from when products are received until being distributed. Prior to the introduction of the automated moisture analyzer, processors relied upon private laboratories for moisture sampling and analysis which utilized the Association of Official Analytic Chemists (AOAC) standard air-drying method. The AOAC air-drying method determines moisture by drying a sample of 2-5g at temperatures of 100-102°C (212-215°F) for a period of 18-24 hours. Results are then reported as a percentage of moisture by weight (Equation 2) (DuPaul *et al*., 1996). However, this practice proved to be exceedingly expensive and untimely for commercial purposes as results could often take multiple days for results. Processors require moisture analysis results in real time to continue operations and to label products appropriately, thus a much more rapid method of analysis is required. One method was the introduction of automated moisture analyzers such as the Ohaus moisture balance (MB) to provide in-house assessments (Fisher, 2005).

$$Moisture\ content(\%) = \frac{(Sample\ weight - Sample\ weight\ after\ drying)}{Sample\ weight}\ x\ 100 \qquad (2)$$

Virginia Sea Grant first introduced the use of automated moisture analyzers to the scallop industry prior to the 1992 FDA interim agreement. Automated moisture analyzers such as the Ohaus MB rapidly remove moisture for scallop samples at specific temperatures utilizing infrared heat in as little as 20 minutes. Drying parameters utilized by automated moisture analyzers were established for scallops through multiple testings against the standard AOAC method (Fisher, 2005).

Although methods of moisture analysis through drying are well-established and provide accurate results there are still concerns. Drying renders individual samples useless for replicable testing. If improper or inadequate results are obtained, the process must be repeated at the expense of time and additional products (Fernández-Segovia *et al*., 2012; Vidaček *et al*. 2008). These limitations may act as a deciding factor in the number of tests completed as to limit product loss, which in turn, can limit accuracy of testing due to inadequate sample sizes. Drying also causes significant physical changes and destruction of individual samples such that scallops cannot be sold or consumed after testing. Additionally, there is little information available for the validity of drying methods in identifying previously frozen scallop products. It would be very valuable to the scallop industry to have a rapid, accurate and non-destructive method of assessing moisture, degradation, and identification of previously frozen products that has limited effects upon samples.

2.0 Study Objectives

The primary objective of this study was to analyze the capabilities of bioelectrical impedance analysis (BIA) in identifying previously frozen from fresh sea scallop products. The ability to identify previously frozen sea scallop products would allow for increased quality assurance and identification of fraudulent products in a rapid and cost-effective manner that supersedes the capabilities of existing methods. In order to realize this objective a standard operating procedure was developed to limit sources of error associated with BIA in the assessment of sea scallops.

3.0 Materials and Methods

3.1 Obtaining sea scallops

Sixty (60) sea scallops were used in this study and were acquired in a market ready form directly through Bristol Seafoods (5 Portland Fish Pier, Portland, ME 04101) and then placed in refrigeration at 3°C (38°F) and/or freezer at -20°C (-5°F) until needed for testing. Of the 60 scallops used during this study, 50 (scallops 1-50) were fresh at the time they were acquired in either a gallon or half gallon container and had not be subjected to Individual Quick Freeze (IQF). IQF is used to rapidly freeze products individually and generally operates within temperatures of -32°C to -41°C (-25°F to -42°F) (Handy, 2019). The remaining 10 scallops (scallops 51-60) had been subjected to IQF frozen and in a sealed bag at the time of being acquired. Each scallop used during this study was harvested from North Atlantic region of the United States between December 2019 and February 2020.

3.2 CQR programming and probe choice

The BIA system used in this study was a Certified Quality Reader (CQR) (Certified Quality Food Inc., Clinton Township, MI 48035). The system was comprised of the measurement unit and probe which was outfitted with two sets of 33-mm long non-penetrating electrodes 2.5 mm apart (Figure 6). Prior to each testing protocol the CQR was reformatted using Certified Quality Foods software on a PC account for scallop identity and specific characteristics. After each testing period, measurements were downloaded from the CQR and stored on ClicData software (ClicData LLC., Scottsdale, AZ 85258) interface for further analysis. The electrical frequency used in this study was preset by manufacturer at 50kHz.

Figure 6: BIA device used in this study was a Certified Quality Reader (CQR) (Certified Quality Food Inc., Clinton Township, MI) The device was outfitted with a handheld probe with four 33-mm long non-penetrating electrodes.

3.3 Sampling Procedure Protocols

Sampling of scallops followed recommended protocols for the use of bioelectrical impedance analysis (BIA) as outlined by Cox et al. (2011) to limit sources of error. Readings were collected by pressing electrodes perpendicularly upon the surface of each scallop with a limited amount of pressure so as to not puncture the scallops but enough to trigger the BIA device to take readings. Samplings were done upon a dry, non-conductive cutting board which was wiped dry between each sampling. Both the cutting board and electrodes were kept in refrigeration when not being used in testing. Temperature measurements were taken using an infrared thermometer at distance of 15 cm (6 in) from the surface of each scallop prior to each testing period.

3.4 Effect of Blotting Testing Protocols

Ten (10) fresh scallops (scallops 1-10) were selected from a container, choosing visually those with the least amount of separation of muscle fibers. Each sample was recorded for weight and temperature then placed on a dry non-conductive cutting board before being placed in refrigeration for 10 minutes. After 10 minutes the non-conductive cutting board with scallop samples was removed from refrigeration, placed on a countertop, and recorded for temperature. Electrodes were also removed at that time and immediately replaced into the probe attached to the CQR. Upon replacing electrodes and recording temperature each scallop was then subjected to BIA for a total of 10 readings per scallop before moving onto the next scallop. Once 100 readings were collected and recorded, each scallop was then lightly blot dried using a paper towel and returned to a dry non-conductive cutting board. Following blot drying treatment, the non-conductive cutting board and 10 scallops were again returned to refrigeration along with electrodes for 10 minutes. After 10 minutes the process of temperature measurement and electrode replacement was repeated, and scallops were again subjected to BIA measurement. Once an additional 100 readings were collected each sample was again blot dried, placed on a dry non-conductive cutting board, and returned to refrigeration for 10 minutes. After 10 minutes the process of temperature measurement and electrode replacement was repeated, and scallops were again subjected to BIA measurement for a total of 100 readings. After the final 100 readings were collected and recorded samples were discarded.

3.5 Effect of Orientation Testing Protocol

Ten (10) fresh scallops (scallops 11-20) were selected from a container, choosing visually those with the least amount of separation of muscle fibers. Each were pat dried using a paper towel and weighed before being placed upon a cold non-conductive cutting board. The orientation at which they were placed was uniform throughout, having one end flat upon the cutting board to have the opposite end parallel to the cutting board (Figure 7). The non-conductive cutting board with the 10 scallops was then placed into a refrigerator for a period of 10 minutes along with electrodes. After 10 minutes the non-conductive cutting board, scallops, and electrodes were removed from refrigeration and electrodes were immediately replaced into the probe connected to CQR. Temperatures for each scallop were recorded prior to 10 BIA readings taken for each of the 10 scallops. After completing readings for "end 1" each scallop was tilted 90° to the right so each scallop is laying on its "side" (Figure 7) and placed into refrigerator for 10 minutes along with electrodes. After 10 minutes the non-conductive cutting board, scallops, and electrodes were removed from refrigeration and electrodes were again reattached to probe connected to CQR. Temperatures were again recorded for each scallop prior to 10 readings being taken from the "side" of each of the 10 scallops. After completing readings upon the "side" of each scallop again each scallop was tilted 90° to the right, whereas "end 1" was flat upon the non-conductive cutting board (Figure 7). The non-conductive cutting board with the scallops was then returned to refrigeration for a period of 10 minutes along with electrodes. After 10 minutes the non-conductive cutting board, scallops, and electrodes were removed from refrigeration and electrodes reattached to the probe connected to CQR. Temperatures for each scallop was again recorded prior to 10 BIA readings taken for each of the 10 scallops upon "End 2".

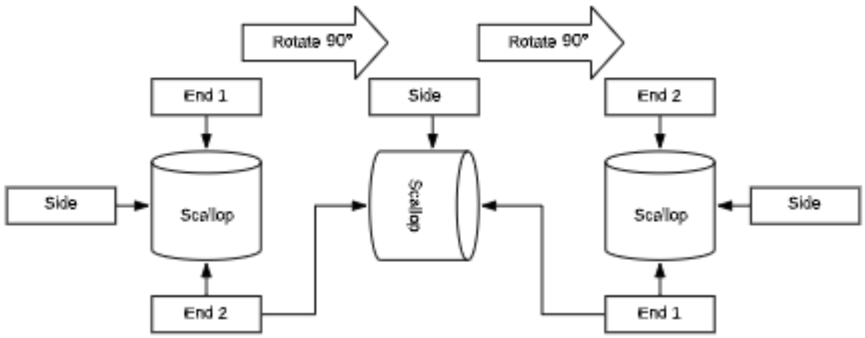

Figure 7: Illustration of scallop orientation during orientation testing.

3.6 Effect of Freezing Testing Protocol

Thirty (30) fresh scallops were selected from a container, choosing visually those with the least amount of separation of muscle fibers, and dividing them among 10 plastic containers. Each scallop was given a number and then placed in refrigerator until needed for testing. During testing intervals only 1 container containing 3 scallops was removed at a time, weighing each scallop, and recording temperatures after being blot dried with a paper towel. Each scallop was then placed with one end on a cold, non-conductive cutting board. After replacing the non-penetrating electrodes that had been refrigerated overnight, 10 readings from each scallop were taken using the CQR before moving onto the next scallop. After each of the 3 scallops within each container had been measured the container was returned to refrigeration before moving onto the next container. These steps were repeated until all 30 scallops (scallops 21-50) had been measured for a total of 300 readings. Once complete the 10 containers containing the 30 scallops were placed into a freezer for a period of 12 hours, then replaced back into refrigerator for another 12 hours allowing scallops to thaw. The non-conductive cutting board and electrodes were placed in the refrigerator when not being used and removed at time of testing. After allowing scallops to thaw, each container was removed one at a time and again blot dried using a paper towel, weighed, and recorded for temperatures. Following the same steps, each of the 3 scallops per container were measured using the CQR a total of 10 times each and then returned to the refrigerator before moving onto the next container. These steps were repeated until all 30 scallops had been measured for an additional 300 readings. Following completion of BIA readings, the non-conductive cutting board and electrodes were once again placed in the refrigerator until needed for testing. Additionally, the 10 containers were placed into freezer for a period of 24 hours and then allowed to thaw in refrigerator for a period of 24 hours. After allowing to thaw each container was again removed one at a time then blot dried using a paper towel, weighed, and recorded for temperature. Following the same steps, each of the 3 scallop per container were measured using the CQR a total of 10 times each, resulting in additional 300 readings. At the conclusion of testing the 10 containers were then placed back into refrigerator for possible future use. Contact from the surface of the scallops with electrodes was not interrupted between each reading, and the electrodes were held at constant pressure, and the location of contact kept the same and stationary.

The remaining 10 scallops used in the study were acquired frozen and sealed in a plastic bag. The scallops were removed from the plastic bag and placed into a glass container and allowed to thaw for 12 hours in refrigerator. Again, the non-conductive cutting board and electrodes which were kept in refrigerator overnight were removed and electrodes replaced into the CQR. Once thawed, each scallop was individually blot dried using a paper towel, weighed, and recorded for temperature before being placed with one end upon the non-conductive cutting board. Each scallop was then measured 10 times each for a total of 100 readings. As previously, contacts from the surface of the scallops with electrodes was not interrupted between each reading, and the electrodes were held at constant pressure and location of contact kept stationary.

3.7 Statistical Analysis Procedures

Statistical analyses of all three testing treatments were preformed similarly. Initial analyses were done using ANOVA for each individual scallop across each protocol for blot testing, orientational testing, and effects of freezing. Preliminary analysis was done using actual (non-normalized) readings. However, non-normalized readings did not account for weight differences between individual samples nor weight changes within individual samples due to treatments. Thus, it was decided to normalize BIA values to the weights of individual scallops for secondary analyses to account for differences in weights between individual samples as well as changes in weight among individual samples due to treatments.

Analyses of non-normalized data using ANOVA was performed for individual scallops to test significance in treatments within each sample. Analyses of normalized data using ANOVA was performed to test significance in treatments across all samples. Post hoc analysis was performed using Tukey's HSD (Equation 3) using information provided by ANOVAs to assess significance of treatments within each testing protocol (Salkind, 2010).

$$Tukey's\ HSD = q\sqrt{\frac{MS_w}{n_k}} \quad (3)$$

In initial post hoc testing for all testing protocols, values of q=3.51 were obtained based on a Studentized Range q Table using $\alpha = 0.05$, df=27, and k=3. This value was constant among all initial post hoc testing for each testing protocol as each scallop was measured the same amount of times (n=10); therefore, n_k=10 was obtained for all initial post hoc testing. However, MS_w values varied between individuals across all testing protocols. MS_w values were dependent upon the outcomes of individual ANOVA results for resistance, reactance, impedance, and phase angles (Appendix 2, Appendix 4, and Appendix 6). Once HSD was calculated it was compared to the differences in averages of each treatment for resistance, reactance, impedance, and phase angles for each individual scallop. Differences in averages between treatments that were greater that the calculated HSD were identified as significant based upon Tukey's HSD (Salkind, 2010).

In secondary post hoc testing for blot testing and orientational testing, q=3.33 was obtained based on a Studentized Range q Table using $\alpha = 0.05$, df=297, and k=3. This value was constant among all secondary post hoc testing for blot and orientational testing protocols as the sample number of scallops (n=10) were measured the same amount of times for a total of 100 readings; therefore, n_k=100 for secondary analysis of blot and orientational testing protocols. However, MS_w varied similarly to initial post hoc testing as values used were dependent upon the results of ANOVA for resistance, reactance, impedance, and phase angles. Similar to the initial post hoc testing, once HSD was calculated for resistance, reactance, impedance, and phase angle the differences between treatment averages were calculated and compared to HSD. Differences in averages between treatments that were greater than the calculated HSD were identified as significant based upon Tukey's HSD.

In secondary post hoc testing for effect of freezing, q=3.32 was obtained based on a Studentized Range q Table using $\alpha = 0.05$, df=897, and k=3. This value differed from the secondary analysis due to the larger number of scallops used in effect of freezing testing (n=30). Similarly, each scallop was measured 10 times, therefore n_k=300. Like all other post hoc testing, MS_w were variable as values used were dependent upon the results of ANOVA for resistance, reactance, impedance, and phase angles. Like all previous post hoc testing, once HSD was calculated for resistance, reactance, impedance, and phase angles the differences between treatment averages were calculated and compared to HSD. Differences in averages between treatments that were greater that the calculated HSD were identified as significant based upon Tukey's HSD.

4.0 Results

4.1 Effect of Blot Testing

Blot testing results of the 10 individual ANOVAs for resistance were highly significant between the three treatments (ranged from $p < 0.04$ to $p < 6.6 \times 10^{-11}$).

Blot testing results of the 10 individual ANOVAs for reactance were highly significant between the three treatments (ranged from $p < 0.0003$ to $p < 2.3 \times 10^{-14}$).

Blot testing results for 10 individual ANOVAs for impedance were highly significant between the three treatments (ranged from $p < 0.003$ to $p < 5.0 \times 10^{-12}$).

Blot testing results for the 9 of the 10 individual ANOVAs for phase angle were highly significant (ranged from $p < 0.015$ to $p < 3.7 \times 10^{-12}$).

Based upon these findings, blotting prior to testing proved to be very important. In order to identify if scallops needed to be blotted once or twice, post hoc Tukey's HSD were performed for resistance, reactance, impedance, and phase angles for each individual scallop. Only 1 of 10 scallops showed that blotting twice was significant for resistance, reactance, impedance, and phase angle. Therefore, it was concluded blotting twice was not as important as blotting once based upon individual analyses.

Analyses of data normalized to weight supported findings on non-normalized data for the three treatments. Results of ANOVA for normalized resistance, reactance, impedance, and phase angles were all also highly significant (3.6×10^{-25},1.8×10^{-29},2.8×10^{-27}, and 2.9×10^{-10}, respectively). Secondary post hoc testing using Tukey's HSD showed significance between no blot and blotting once as well as no blot and blotting twice for resistance, reactance, impedance, and phase angles for all treatments. Secondary post hoc testing also showed significance difference between blotting once and blotting twice for normalized values in resistance, reactance, and impedance, but not for phase angles.

4.2 Orientation Testing

Orientation testing results of the 10 individual ANOVAs for resistance were highly significant between the 3 treatments (ranged from $p < 0.006$ to $p < 5.1 \times 10^{-19}$).

Orientation testing results of the 10 individual ANOVAs for reactance were highly significant between the three treatments ($p < 0.002$ to $p < 6.3 \times 10^{-13}$).

Orientation testing results of the 10 individual ANOVAs for impedance were highly significant between the three treatments ($p < 0.006$ to $p < 4.2 \times 10^{-19}$).

Orientation testing results of the 10 individual ANOVAs for phase angle were highly significant between the three treatments ($p < 0.0004$ to $p < 3.3 \times 10^{-15}$).

Initial post hoc testing using Tukey's HSD showed that there were significant differences in resistance, reactance, impedance, and phase angle averages between treatments. In 9 of the 10 scallops there were significant differences in resistance averages from end 1 and side, as well as, end 2 and side. However, there was no significant difference between end 1 and end 2. Similarly, there were significant differences in impedance averages from end 1 and side and end 2 and side; however, no significant difference between end 1 and end 2 in 8 of the 10 scallops. This trend was not observed however in post hoc analysis of reactance or phase angles.

Normalized data supported findings that orientation was significant between the three treatments. Results of ANOVA for normalized resistance, reactance, impedance, and phase angle values were all highly significant (6.2×10^{-25}, 4.0×10^{-6}, 4.7×10^{-24}, and 2.1×10^{-18}, respectively). Secondary post hoc testing using Tukey's HSD had similar results to initial post hoc testing. Secondary post hoc testing showed significant differences in resistance and impedance averages between end 1 and side, as well as, end 2 and side. In addition, post hoc testing found no significant differences in resistance and impedance averages when comparing end 1 and end 2. Therefore, it was concluded that due to the significant differences in resistance and impedance values taken from the side of the scallop compared to either end, measurements should be taken from either end of the scallop.

4.3 Effect of Freezing Testing

Effect of freezing results of the 10 individual ANOVAs for resistance were highly significant between the 3 treatments (ranged from $p < 1.6 \times 10^{-15}$ to $p < 7.8 \times 10^{-36}$).

Effect of freezing results of the 10 individual ANOVAs for reactance were highly significant (ranged from $p < 3.5 \times 10^{-14}$ to $p < 9.8 \times 10^{-43}$).

Effect of freezing results of the 10 individual ANOVAs for impedance were highly significant (ranged from $p < 9.1 \times 10^{-16}$ to $p < 4.5 \times 10^{-36}$).

Effect of freezing results of the 10 individual ANOVAs for phase angle were highly significant (ranged from $p < 3.7 \times 10^{-7}$ to $p < 2.8 \times 10^{-27}$).

Initial post hoc testing using Tukey's HSD showed there were significant differences in resistance, reactance, impedance, and phase angle averages between treatments. Through analysis of post hoc testing results it was observed that there were significant differences between average resistance, reactance, and impedance values from fresh samples and after samples were frozen for 12 hours. However, this trend was not observed in post hoc analysis of phase angle between fresh and frozen for 12 hours average values.

It was observed that average resistance, reactance, and impedance values had greater differences from fresh values after freezing for additional 24 hours. Therefore, the second treatment of longer subjected freezing had a greater effect upon resistance and reactance measurements. Additionally, phase angle average values decreased in all 30 samples after the second freezing treatment when compared to phase angle averages when fresh and after first freezing treatment.

Analysis of normalized data supported individual findings that the effects of freezing was significant between the three treatments. ANOVA results for normalized resistance, reactance, impedance, and phase angles were all highly significant ($4.6x10^{-78}$, $1.1x10^{-105}$, $1.3x10^{-79}$, and $3.4x10^{-154}$, respectively). Post hoc testing using Tukey's HSD had similar results to initial post hoc testing showing there was significant differences in BIA measures when samples were subjected to freezing temperatures. Additionally, differences in measured values increased when subjected to additional freezing treatments of increased duration.

Therefore, it was concluded that previously frozen scallops can be rapidly identified using BIA measurements.

5.0 Discussion

5.1 Establishing a Standard Operating Procedure (SOP)

For BIA to become a useful and effective tool for the assessment of quality and condition in scallop products a standard operating procedure (SOP) needed to be established. An SOP would allow for anyone utilizing BIA to obtain the measurements and information they were seeking while limiting the amount of variability and error associated. It was decided to focus first upon preparation of samples prior to testing by removing excess surface moisture or water by blotting. Blotting has been shown to be important in several studies utilizing BIA, as excess moisture or water was noted as a possible source of error (Cox *et al*., 2011).

Due to common practices in processing and packaging surface moisture can be highly variable in scallop products when packaged. For instance, when multiple samples are taken from the same container it is expected that scallops at the top would have less surface moisture than those at the bottom of the container due to drip loss and gravity. Therefore, to limit variance in surface moisture of scallop products each sample must be blot dried prior to testing. This conclusion was supported by the analyses which found blot drying was significantly important upon BIA measurements. Additionally, statistical analyses of normalized values provided evidence that blotting twice was significant for resistance, reactance, and impedance (Figure 8) which may have been caused by increased drip loss as temperature increased in samples during testing. However, this was not tested further as changes in weight were not recorded between blotting treatments.

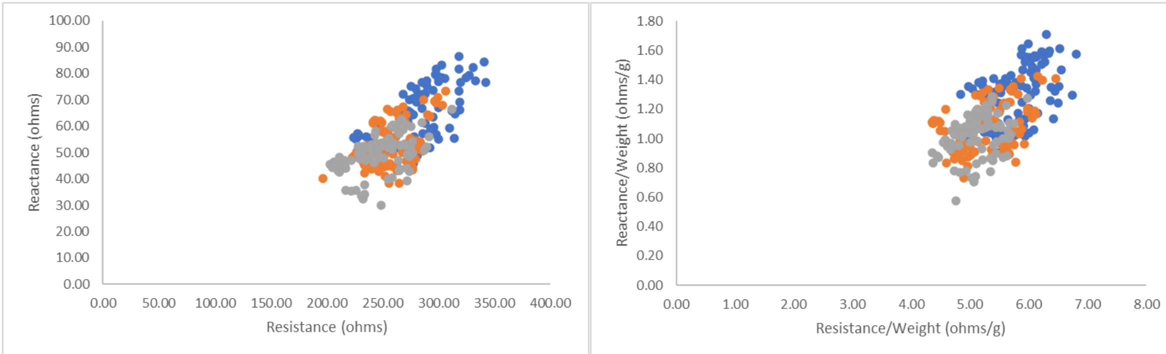

Figure 8: Comparison of non-normalized (left) and normalized (right) BIA measurements in blot testing. (Blue, no blot; orange, blotted one; grey, blotted twice)

The second aspect investigated in establishing SOP for the utilization of BIA for scallop products was orientation. Orientation refers to the positioning of test subject and the location of probes in reference to the test subject. The effect of probe location has been studied extensively by Cox et al. (2011) using brook trout (*Salvelinus fontinalis*). This study used different probe locations in reference to anatomical structures, such as pectoral, dorsal, and anal fins, to assess effect upon impedance measurements. However, due to the significant anatomical and physical differences between scallop adductor muscles and whole fish it was decided that within this study that orientation of samples would be focused upon in terms of probe location. Therefore, testing was designed to assess whether measurements were to be taken perpendicularly from either the ends (top/bottom) or from the side of scallops when placed upon a flat surface.

Observation of individual analyses and post hoc testing showed that, in all samples, resistance and reactance measurements taken from the side of scallops were significantly different than those taken from either end (Figure 9). Individual analyses also showed there were significant differences in resistance and reactance measurements for some samples when comparing end 1 and end 2 (Appendix 4). Structure variations, such as, separation of muscular tissue or temperature variations may be responsible for differences in measurements between ends. However, this was not investigated further. Therefore, it was concluded that BIA measurements should be taken from either end of the scallop adductor and not from the side.

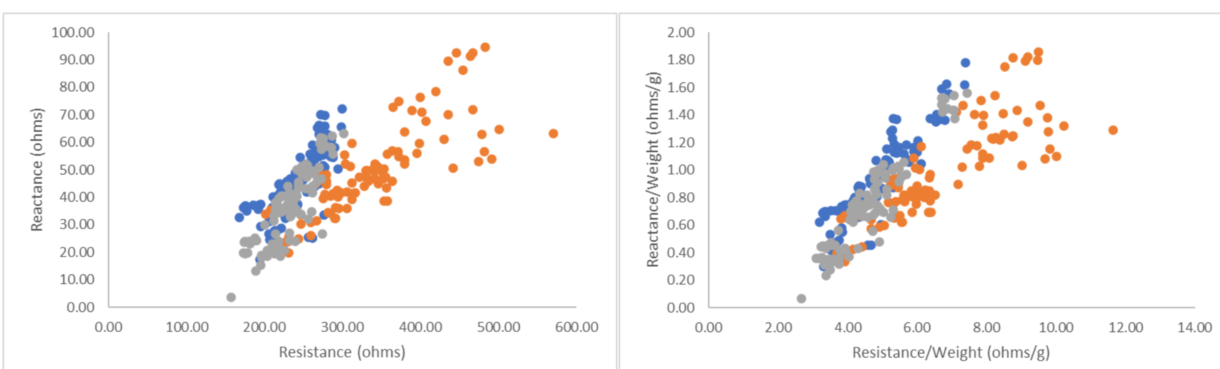

Figure 9: Comparison of non-normalized (left) and normalized (right) BIA measurements in orientational testing. (Blue, end 1; orange, side; grey, end2)

5.2 Identifying Previously Frozen Scallops Through BIA

Once an SOP for blotting procedure and orientation was established for scallops, the effects of freezing treatments were assessed. Through analysis of BIA measurements of resistance and reactance after freezing and thawing treatments it was observed that BIA was significantly sensitive to the effects of freezing upon scallops. Additionally, BIA was sensitive to the proportion of thawed and frozen tissue within a sample at the time of testing as it related to duration of thawing. These findings are similar to those made by Cox (2015) who used albacore tuna to assess the sensitivity of BIA to detect the effect of freezing upon tissues.

After initial freezing treatment, it was observed through individual analyses that resistance measurements changed in all samples. However, not all samples exhibited changes in resistance in a similar way. In 80% of scallop samples, resistance had decreased significantly after initial freezing treatment. Whereas, the remaining 20% exhibited a significant increase (Figure 10). Through these findings it was concluded that sample that exhibited increasing resistance measurements had not completely thawed at the time of testing. Conclusion was based upon the understanding that tissues become more resistive to electrical current when frozen. As tissue cells and extracellular fluid freeze, the conductivity of water and suspended electrolytes in extracellular fluid can no longer carry an electrical charge. Therefore, the electrical current must be carried by highly resistive H+ protons. Thus, when there is a higher proportion of frozen tissue to thawed within a sample resistance will be increased.

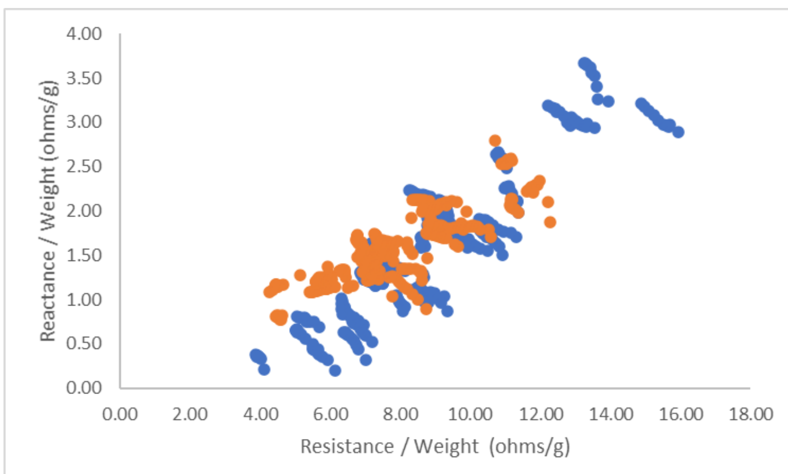

Figure 10: Comparison of normalized BIA measurements from scallops when fresh (blue) and after initial freezing and thawing treatment (orange).

Reactance also increased significantly in 53% of scallop samples after initial freezing and thawing treatment. However, a definitive cause for increases was unable to be definitively determined. Reactance is sensitive to cell volumes and is reflective of the capacitance of cellular membranes. In living organisms, growth causes the expansion of cell volumes. As cell volume increases the capacitance of cellular membranes will also increase. Due to scallops having been harvested and shucked prior to being acquired it is reasonable to believe that in vivo cellular processes could not be responsible for cellular growth and increased cell volume. Therefore, it was theorized that increased reactance measures after initial freezing were due to frozen intracellular fluid causing cells to expand. When cells are expanded the surface area of cells would be increased. This could allow for greater capacitance of the lipid bilayer of cells to be observed if cellular membranes had not begun degradation.

Resistance and reactance are integral to the calculations of impedance phase angle. Therefore, similar trends of increasing impedance and phase angle were observed in several samples after initial freezing and thawing treatment. Impedance increased in 20% of samples, whereas, within these samples both resistance and reactance had increased. Thus, impedance is highly correlated to both measures. In contrast, phase angle increased in 60% of samples and included the 20% previously mentioned. However, in the additional 40% of samples in which phase angle increased only reactance was observed to increase (Appendix 6). Therefore, it was concluded that phase angle is more relative to reactance than resistance. These findings could be useful in establishing BIA models for future works.

Secondary freezing and thawing treatment had a significantly negative effect upon BIA measurements based upon initial and secondary analysis. After the secondary freezing and thawing treatment all samples showed significant decreases in resistance, reactance, impedance, and phase angle. This included those which originally exhibited increases in BIA measurements after initial freezing and thawing treatment. As no samples exhibited an increase in resistance or reactance after secondary freezing and thawing treatment it was concluded that all samples had properly thawed after 24 hours at 3°C. This conclusion provides support for the previous claims that some samples had not completely thawed after initial freezing and thawing treatment.

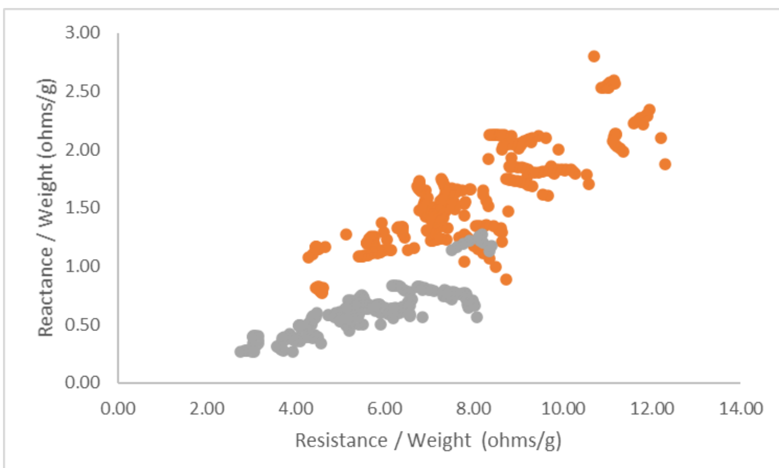

Figure 11: Comparison of normalized BIA measurements from scallops after initial (orange) and secondary (grey) freezing and thawing treatments.

Through individual and normalized scallop analyses, it was observed secondary freezing and thawing treatment were much more significant upon sample than the initial freezing and thawing treatment. However, the cause of significance associated to secondary freezing and thawing treatment was unable to be definitively identified due to unintended confounding factors in test design. Although temperatures were maintained constant for both treatments during freezing and thawing, the length of freezing and thawing periods differed between treatments. Additionally, the factor of twice frozen may have presented a significant effect upon sampling. These possible confounding factors were compared to conclusions made in previous studies using BIA to assess the effects of freezing in fish.

To assess the factor of multiple freezing cycles the results of this study were compared to the study concluded by Vidaček *et al.* (2008). The study utilized bioelectrical impedance spectroscopy (BIS) (range of 1Hz to 1Mhz) to assess the effect of multiple freezing cycles on BIA measurements with fresh and frozen sea bass (*Dicentrarchus labrax*) using slow-freezing and fast freezing. The results of the study found that reactance measures can be used to differentiate between once and twice frozen samples, as well as, between samples slow-frozen and fast frozen. These findings are similar to those found in this study as reactance decreased significantly in all samples following secondary freezing and thawing. However, this was observed at a frequency of 500kHz in the study by Vidaček *et al.* (2008) which was much greater than the 50kHz frequency used in this study. Additionally, freezing periods utilized in the sea bass study were uniform across freezing cycles and were far greater than those in this study (14 days versus 12 hours and 24 hours).

Further comparisons were made to the study by Fernández-Segovia *et al*. (2012) which utilized BIS to assess the effects of multiple freezing cycles on BIA measurement in salmon (*Salmo salar*). Although it was observed that there were significant differences in BIA measurements between fresh and frozen products, Fernández-Segovia *et al*. (2012) found no differences in samples when subjected to multiple freezing cycles. Additionally, no differences were observed between samples of different freezing periods. However, BIA measurements were not taken from samples prior to freezing treatments or between freezing cycles for those subjected to multiple freezing cycles. Therefore, the effect of upon individual samples due to initial and/or secondary freezing was not conducted.

BIA measurements were performed on scallop samples using individual quick freeze (IQF) (-32°C to -41°C) in addition to those slowly frozen using a conventional household freezer (-20°C). Statistical analysis could not performed to assess the effect of IQF in comparison to slow freezing due to IQF scallops having been prior to being acquired. Therefore, BIA measurements of scallops when fresh, prior to IQF, could not be obtained. However, these measurements provided support that BIA in the future could be used to identify previously frozen products based upon impedance measurements (Figure 12).

With this study, the potential for BIA to be utilized within the scallop industry to identify previously frozen products was demonstrated.

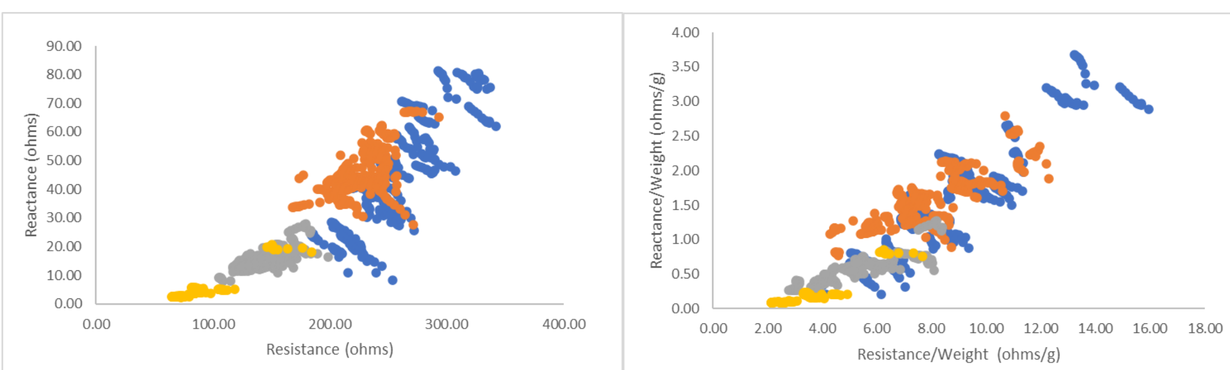

Figure 12: Comparison of BIA non-normalized (left) and normalized (right) measurements of samples in effect of freezing testing. Included are samples that were thawed after being frozen using Individual Quick Freeze (IQF). (Blue, fresh; orange, initial freezing; grey, secondary freezing; yellow, IQF)

5.3 Future of BIA in the Scallop Value Chains

The establishment of accurate and precise BIA models would give harvesters, processors, and purchasers the rapid ability to quantitatively assess the value of their products inexpensively and allow for better promotion of scallop quality and increase product marketability. With the use of BIA devices as those used in this study, large collections of data can be compiled simply over extended temporal and regional scale and allow for processors to identify when and where the highest quality products are being harvested and by which vessels. In addition, this same data could be used to develop better standard operating procedures associated with maintaining the highest quality scallops from point of harvest through the handling and storage process. This information could also be useful to fisheries and aquaculture governing bodies to provide physiological and quantitative data for use in future policies and regulations.

Further development for the utilization of BIA in scallop value chains will provide a useful and valuable tool to the industry. Having an ability to assess quality in products rapidly, cheaply, and with little effect upon samples could be valuable to both purchasers and concerned consumers alike. Scallop products are considered a high value item, demanding high prices throughout the year and being able to rapidly prove their quality would be exceedingly valuable.

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Appendices

Appendix 1: U.S. Domestic Landings, by species, 2018

Table 1: Summary of U.S. domestic landings volume and value, by species, in 2018 (NMFS, 2020).

Species	Thousand pounds	Metric tons	Thousand dollars ($USD)	Price/ Pound ($/lb)	Price/ Ton ($/mt)	Share of Volume (%)	Share of Value (%)
Fish	**8,240,663**	**3,737,940**	**2,519,507**	**0.31**	**674.04**	**87.80%**	**45.22%**
Salmon	575,972	261,259	598,067	1.04	2,289.17	6.14%	10.73%
Tuna	51,684	23,444	149,053	2.88	6,357.83	0.55%	2.68%
Flatfish	546,999	248,117	242,553	0.44	977.58	5.83%	4.35%
Manhaden	1,581,578	717,399	161,088	0.10	224.54	16.85%	2.89%
Other	5,484,430	2,487,721	1,368,746	0.25	550.20	58.44%	24.57%
Shellfish	**1,107,717**	**502,457**	**3,026,945**	**2.73**	**6,024.29**	**11.80%**	**54.33%**
Crustaceans	742,621	336,851	1,837,879	2.47	5,456.06	7.91%	32.99%
Crabs	289,021	131,099	644,912	2.23	4,919.27	3.08%	11.58%
Shrimp	289,178	131,170	496,114	1.72	3,782.22	3.08%	8.90%
Lobsters	153,244	69,511	684,303	4.47	9,844.53	1.63%	12.28%
Other	11,178	5,071	12,550	1.12	2,474.86	0.12%	0.23%
Mollusks	341,470	154,890	1,167,511	3.42	7,537.68	3.64%	20.96%
Squid	161,628	73,314	102,037	0.63	1,391.78	1.72%	1.83%
Clams	85,670	38,860	244,107	2.85	6,281.70	0.91%	4.38%
Scallops	58,382	26,482	540,583	9.26	20,413.22	0.62%	9.70%
Oysters	30,304	13,746	258,748	8.54	18,823.51	0.32%	4.64%
Mussels	3,155	1,431	11,158	3.54	7,797.34	0.03%	0.20%
Conch	2,331	1,057	10,878	4.67	10,291.39	0.02%	0.20%
Other shellfish	23,626	10,717	21,555	0.91	2,011.29	0.25%	0.39%
Other	**36,988**	**16,778**	**24,952**	**0.67**	**1,487.19**	**0.39%**	**0.45%**
Total	**9,385,368**	**4,257,175**	**5,571,404**	**0.59**	**1,308.71**		

Appendix 2: Individual Blot Testing Initial ANOVAs

Scallop 1

Anova: Single Factor
Resitance

SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	3061.29	306.129	207.994
Blot 1	10	2770.87	277.087	55.24629
Blot 2	10	2648.34	264.834	115.865

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	8996.169	2	4498.085	35.59501	2.69E-08	3.354131
Within Groups	3411.947	27	126.3684			
Total	12408.12	29				

Anova: Single Factor
Reactance

SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	638.96	63.896	35.72114
Blot 1	10	470.36	47.036	10.75216
Blot 2	10	505.23	50.523	10.99549

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1584.186	2	792.0932	41.34904	6.04E-09	3.354131
Within Groups	517.2191	27	19.15626			
Total	2101.405	29				

	R	Xc	Z	P
HSD	12.46	4.85	12.84	0.72
No Blot- Blot 1	29.04	16.86	31.70	2.16
No Blot- Blot 2	41.30	13.37	43.13	0.98
Blot 1 -Blot 2	12.25	-3.49	11.43	-1.18

Anova: Single Factor
Impedance

SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	3127.554	312.7554	223.4259
Blot 1	10	2810.593	281.0593	60.72934
Blot 2	10	2696.244	269.6244	118.3075

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	9985.594	2	4992.797	37.21684	1.74E-08	3.354131
Within Groups	3622.165	27	134.1542			
Total	13607.76	29				

Anova: Single Factor
Phase angle

SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	117.8311	11.78311	0.661668
Blot 1	10	96.27373	9.627373	0.216379
Blot 2	10	108.0441	10.80441	0.386271

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	23.30148	2	11.65074	27.6451	2.93E-07	3.354131
Within Groups	11.37887	27	0.42144			
Total	34.68034	29				

Scallop 2

Anova: Single Factor
Resistance

SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	2991.26	299.126	103.4948
Blot 1	10	2640.76	264.076	31.33518
Blot 2	10	2573.55	257.355	104.1289

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	10061.64	2	5030.818	63.15919	6.57E-11	3.354131
Within Groups	2150.631	27	79.65298			
Total	12212.27	29				

Anova: Single Factor
Reactance

SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	785.08	78.508	24.84151
Blot 1	10	630.66	63.066	13.40054
Blot 2	10	567.03	56.703	17.42962

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2514.671	2	1257.335	67.7545	3E-11	3.354131
Within Groups	501.045	27	18.55722			
Total	3015.716	29				

	R	Xc	Z	P
HSD	9.89	4.78	10.53	0.65
No Blot- Blot 1	35.05	15.44	37.75	1.26
No Blot- Blot 2	41.77	21.81	45.73	2.28
Blot 1 -Blot 2	6.72	6.36	7.98	1.02

Anova: Single Factor
Impedance

SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	3092.683	309.2683	120.5294
Blot 1	10	2715.211	271.5211	33.35732
Blot 2	10	2635.361	263.5361	116.6009

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	11933.49	2	5966.747	66.17768	3.9E-11	3.354131
Within Groups	2434.389	27	90.16254			
Total	14367.88	29				

Anova: Single Factor
Phase angle

SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	146.9608	14.69608	0.271601
Blot 1	10	134.3115	13.43115	0.511103
Blot 2	10	124.1325	12.41325	0.235237

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	26.15828	2	13.07914	38.54588	1.23E-08	3.354131
Within Groups	9.161469	27	0.339314			
Total	35.31975	29				

Scallop 3

Anova: Single Factor
Resistance

SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	2851.88	285.188	83.01475
Blot 1	10	2465.77	246.577	22.53278
Blot 2	10	2532.49	253.249	72.20045

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	8518.082	2	4259.041	71.88336	1.53E-11	3.354131
Within Groups	1599.732	27	59.24933			
Total	10117.81	29				

Anova: Single Factor
Reactance

SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	746.16	74.616	5.03376
Blot 1	10	615.25	61.525	5.330028
Blot 2	10	523.77	52.377	19.68878

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2498.778	2	1249.389	124.7203	2.3E-14	3.354131
Within Groups	270.4731	27	10.01752			
Total	2769.251	29				

	R	Xc	Z	P
HSD	8.53	3.51	8.78	0.61
No Blot- Blot 1	38.61	13.09	40.65	0.66
No Blot- Blot 2	31.94	22.24	36.17	3.00
Blot 1 -Blot 2	-6.67	9.15	-4.48	2.34

Anova: Single Factor
Impedance

SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	2947.95	294.795	83.23743
Blot 1	10	2541.474	254.1474	21.89024
Blot 2	10	2586.241	258.6241	82.95433

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	9935.305	2	4967.652	79.23649	5.03E-12	3.354131
Within Groups	1692.738	27	62.694			
Total	11628.04	29				

Anova: Single Factor
Phase angle

SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	146.6908	14.66908	0.182119
Blot 1	10	140.1407	14.01407	0.299062
Blot 2	10	116.7131	11.67131	0.433544

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	49.6808	2	24.8404	81.46848	3.65E-12	3.354131
Within Groups	8.23252	27	0.304908			
Total	57.91332	29				

Scallop 4

Anova: Single Factor
Resistance

SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	2698.05	269.805	42.35825
Blot 1	10	2448.19	244.819	231.3316
Blot 2	10	2408.07	240.807	49.66753

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4937.601	2	2468.801	22.90469	1.53E-06	3.354131
Within Groups	2910.217	27	107.7858			
Total	7847.818	29				

Anova: Single Factor
Reactance

SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	634.04	63.404	18.49627
Blot 1	10	468.47	46.847	8.307357
Blot 2	10	517.07	51.707	5.872423

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1448.579	2	724.2894	66.49727	3.7E-11	3.354131
Within Groups	294.0845	27	10.89202			
Total	1742.663	29				

	R	Xc	Z	P
HSD	11.51	3.66	11.73	0.62
No Blot- Blot 1	24.99	16.56	27.91	2.38
No Blot- Blot 2	29.00	11.70	30.88	1.10
Blot 1 -Blot 2	4.01	-4.86	2.96	-1.28

Anova: Single Factor
Impedance

SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	2771.786	277.1786	46.19022
Blot 1	10	2492.651	249.2651	237.3244
Blot 2	10	2463.014	246.3014	52.48781

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5804.525	2	2902.262	25.91287	5.23E-07	3.354131
Within Groups	3024.022	27	112.0008			
Total	8828.547	29				

Anova: Single Factor
Phase angle

SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	132.2168	13.22168	0.642179
Blot 1	10	108.388	10.8388	0.123136
Blot 2	10	121.1806	12.11806	0.168577

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	28.442	2	14.221	45.68301	2.16E-09	3.354131
Within Groups	8.405029	27	0.311297			
Total	36.84703	29				

Scallop 5

Anova: Single Factor
Resistance

SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	2839.77	283.977	81.06256
Blot 1	10	2504.08	250.408	143.4357
Blot 2	10	2764.17	276.417	95.71882

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	6201.665	2	3100.832	29.05059	1.86E-07	3.354131
Within Groups	2881.954	27	106.739			
Total	9083.619	29				

Anova: Single Factor
Reactance

SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	532.94	53.294	16.25025
Blot 1	10	447.76	44.776	6.335849
Blot 2	10	474.16	47.416	25.17487

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	380.256	2	190.128	11.94247	0.000193	3.354131
Within Groups	429.8487	27	15.92032			
Total	810.1047	29				

	R	Xc	Z	P
HSD	11.45	4.42	11.76	0.72
No Blot- Blot 1	33.57	8.52	34.57	0.48
No Blot- Blot 2	7.56	5.88	8.48	0.91
Blot 1 -Blot 2	-26.01	-2.64	-26.09	0.42

Anova: Single Factor
Impedance

SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	2889.539	288.9539	84.92972
Blot 1	10	2543.864	254.3864	146.0089
Blot 2	10	2804.772	280.4772	106.6241

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	6491.644	2	3245.822	28.84639	1.98E-07	3.354131
Within Groups	3038.064	27	112.5209			
Total	9529.708	29				

Anova: Single Factor
Phase angle

SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	106.274	10.6274	0.489951
Blot 1	10	101.432	10.1432	0.189889
Blot 2	10	97.18678	9.718678	0.59383

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4.134837	2	2.067418	4.869592	0.015637	3.354131
Within Groups	11.46303	27	0.424557			
Total	15.59787	29				

Scallop 6

Anova: Single Factor
Resistance

SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	2805.66	280.566	244.4143
Blot 1	10	2714.37	271.437	52.40629
Blot 2	10	2341.65	234.165	172.1365

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	12085.31	2	6042.656	38.65592	1.19E-08	3.354131
Within Groups	4220.614	27	156.319			
Total	16305.93	29				

Anova: Single Factor
Reactance

SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	520.48	52.048	23.97257
Blot 1	10	492.26	49.226	34.81085
Blot 2	10	358.68	35.868	7.755329

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1493.974	2	746.9871	33.67904	4.61E-08	3.354131
Within Groups	598.8488	27	22.17958			
Total	2092.823	29				

	R	Xc	Z	P
HSD	13.86	5.22	14.31	0.81
No Blot- Blot 1	9.13	2.82	9.46	0.24
No Blot- Blot 2	46.40	16.18	48.46	1.79
Blot 1 -Blot 2	37.27	13.36	39.00	1.55

Anova: Single Factor
Impedance

SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	2853.648	285.3648	260.8475
Blot 1	10	2759.04	275.904	63.05442
Blot 2	10	2369.038	236.9038	175.8182

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	13196.6	2	6598.3	39.61198	9.32E-09	3.354131
Within Groups	4497.481	27	166.5734			
Total	17694.08	29				

Anova: Single Factor
Phase angle

SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	104.9636	10.49636	0.306606
Blot 1	10	102.6115	10.26115	1.052983
Blot 2	10	87.10575	8.710575	0.243041

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	18.82881	2	9.414404	17.62304	1.27E-05	3.354131
Within Groups	14.42367	27	0.53421			
Total	33.25247	29				

Scallop 7

Anova: Single Factor
Resistance
SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	2777.53	277.753	41.08651
Blot 1	10	2453.77	245.377	349.2648
Blot 2	10	2251.07	225.107	162.2393

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	14102.27	2	7051.133	38.28042	1.31E-08	3.354131
Within Groups	4973.315	27	184.1969			
Total	19075.58	29				

Anova: Single Factor
Reactance
SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	689.07	68.907	14.76065
Blot 1	10	534.37	53.437	21.8414
Blot 2	10	491.64	49.164	26.92196

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2157.885	2	1078.942	50.9544	6.83E-10	3.354131
Within Groups	571.7161	27	21.17467			
Total	2729.601	29				

	R	Xc	Z	P
HSD	15.05	5.10	15.61	0.67
No Blot- Blot 1	32.38	15.47	35.05	1.64
No Blot- Blot 2	52.65	19.74	55.76	1.63
Blot 1 -Blot 2	20.27	4.27	20.71	-0.01

Anova: Single Factor
Impedance
SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	2861.852	286.1852	48.00384
Blot 1	10	2511.387	251.1387	365.2663
Blot 2	10	2304.28	230.428	181.5788

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	15886.82	2	7943.412	40.06098	8.32E-09	3.354131
Within Groups	5353.641	27	198.283			
Total	21240.46	29				

Anova: Single Factor
Phase angle
SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	139.2766	13.92766	0.320491
Blot 1	10	122.8744	12.28744	0.30643
Blot 2	10	122.9537	12.29537	0.45729

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	17.84906	2	8.924529	24.69407	7.99E-07	3.354131
Within Groups	9.757899	27	0.361404			
Total	27.60696	29				

Scallop 8

Anova: Single Factor
Resistance
SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	3216.15	321.615	321.8038
Blot 1	10	2872.13	287.213	298.8917
Blot 2	10	2713.75	271.375	296.5887

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	13194.66	2	6597.329	21.57672	2.52E-06	3.354131
Within Groups	8255.558	27	305.7614			
Total	21450.22	29				

Anova: Single Factor
Reactance
SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	766.17	76.617	38.69171
Blot 1	10	647.57	64.757	100.7609
Blot 2	10	580.55	58.055	101.812

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1767.081	2	883.5404	10.98637	0.000323	3.354131
Within Groups	2171.381	27	80.42154			
Total	3938.462	29				

	R	Xc	Z	P
HSD	19.39	9.94	20.42	1.58
No Blot- Blot 1	34.40	11.86	36.13	0.75
No Blot- Blot 2	50.24	18.56	53.00	1.36
Blot 1 -Blot 2	15.84	6.70	16.87	0.61

Anova: Single Factor
Impedance
SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	3306.352	330.6352	345.7629
Blot 1	10	2945.037	294.5037	346.694
Blot 2	10	2776.342	277.6342	325.1073

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	14663.91	2	7331.954	21.61619	2.48E-06	3.354131
Within Groups	9158.078	27	339.1881			
Total	23821.99	29				

Anova: Single Factor
Phase angle
SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	133.9349	13.39349	0.440418
Blot 1	10	126.484	12.6484	2.234998
Blot 2	10	120.3385	12.03385	3.4281

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	9.27147	2	4.635735	2.278556	0.121786	3.354131
Within Groups	54.93164	27	2.034505			
Total	64.20311	29				

Scallop 9

Anova: Single Factor
Resistance
SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	2594.06	259.406	98.58689
Blot 1	10	2473.54	247.354	33.44327
Blot 2	10	2447.26	244.726	122.4946

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1225.532	2	612.7658	7.222469	0.003073	3.354131
Within Groups	2290.723	27	84.8416			
Total	3516.255	29				

Anova: Single Factor
Reactance
SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	520.56	52.056	1.901893
Blot 1	10	475.98	47.598	1.532907
Blot 2	10	513.18	51.318	5.030551

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	114.1894	2	57.09468	20.23354	4.27E-06	3.354131
Within Groups	76.18816	27	2.821784			
Total	190.3775	29				

	R	Xc	Z	P
HSD	10.21	1.86	10.19	0.43
No Blot- Blot 1	12.05	4.46	12.69	0.46
No Blot- Blot 2	14.68	0.74	14.53	-0.49
Blot 1 -Blot 2	2.63	-3.72	1.84	-0.95

Anova: Single Factor
Impedance
SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	2645.86	264.586	95.56018
Blot 1	10	2518.965	251.8965	32.44947
Blot 2	10	2500.521	250.0521	125.6263

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1252.191	2	626.0956	7.405445	0.002729	3.354131
Within Groups	2282.723	27	84.5453			
Total	3534.914	29				

Anova: Single Factor
Phase angle
SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	113.602	11.3602	0.227334
Blot 1	10	108.9751	10.89751	0.129043
Blot 2	10	118.4832	11.84832	0.100739

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4.521249	2	2.260624	14.83624	4.5E-05	3.354131
Within Groups	4.114038	27	0.152372			
Total	8.635286	29				

Scallop 10

Anova: Single Factor
Resistance
SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	2324.37	232.437	69.27673
Blot 1	10	2255.04	225.504	279.6845
Blot 2	10	2116.93	211.693	57.3758

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2230.412	2	1115.206	8.233605	0.001615	3.354131
Within Groups	3657.033	27	135.4457			
Total	5887.446	29				

Anova: Single Factor
Impedance
SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	2392.81	239.281	70.35626
Blot 1	10	2307.716	230.7716	305.5474
Blot 2	10	2166.039	216.6039	58.0087

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2624.611	2	1312.305	9.073068	0.000968	3.354131
Within Groups	3905.211	27	144.6375			
Total	6529.822	29				

Anova: Single Factor
Reactance
SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	568.04	56.804	3.014938
Blot 1	10	489.95	48.995	29.16203
Blot 2	10	458.35	45.835	3.390694

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	637.6168	2	318.8084	26.8903	3.76E-07	3.354131
Within Groups	320.1089	27	11.85589			
Total	957.7257	29				

Anova: Single Factor
Phase angle
SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	10	137.3949	13.73949	0.110176
Blot 1	10	122.3058	12.23058	0.202746
Blot 2	10	122.228	12.2228	0.192205

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	15.25736	2	7.628682	45.3076	2.36E-09	3.354131
Within Groups	4.546134	27	0.168375			
Total	19.8035	29				

	R	Xc	Z	P
HSD	12.90	3.82	13.33	0.45
No Blot- Blot 1	6.93	7.81	8.51	1.51
No Blot- Blot 2	20.74	10.97	22.68	1.52
Blot 1 -Blot 2	13.81	3.16	14.17	0.01

Appendix 3: Normalized Blot Testing Secondary ANOVAs

Anova: Single Factor

Resistance

SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	100	576.1744	5.761744	0.210944
Blot 1	100	524.8683	5.248683	0.24036
Blot 2	100	507.0007	5.070007	0.114057

Tukey's HSD	0.14
No Blot - Blot 1	0.51
No Blot - Blot 2	0.69
Blot 1 - Blot 2	0.18

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	25.78854	2	12.89427	68.42142	3.6347E-25	3.026153
Within Groups	55.97075	297	0.188454			
Total	81.75929	299				

Anova: Single Factor

Reactance

SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	100	130.8497	1.308497	0.038657
Blot 1	100	107.8675	1.078675	0.026368
Blot 2	100	101.9895	1.019895	0.018632

Tukey's HSD	0.06
No Blot - Blot 1	0.23
No Blot - Blot 2	0.29
Blot 1 - Blot 2	0.06

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4.652125	2	2.326063	83.41373	1.7799E-29	3.026153
Within Groups	8.282098	297	0.027886			
Total	12.93422	299				

Anova: Single Factor

Impedance

SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	100	591.0799	5.910799	0.221631
Blot 1	100	536.0368	5.360368	0.245178
Blot 2	100	517.3133	5.173133	0.116377

Tukey's HSD	0.15
No Blot - Blot 1	0.55
No Blot - Blot 2	0.74
Blot 1 - Blot 2	0.19

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	29.40607	2	14.70303	75.63482	2.8232E-27	3.026153
Within Groups	57.73532	297	0.194395			
Total	87.14139	299				

Anova: Single Factor

Phase Angle

SUMMARY

Groups	Count	Sum	Average	Variance
No Blot	100	1279.145	12.79145	2.645803
Blot 1	100	1163.797	11.63797	2.500398
Blot 2	100	1138.366	11.38366	1.992343

Tukey's HSD	0.51
No Blot - Blot 1	1.15
No Blot - Blot 2	1.41
Blot 1 - Blot 2	0.25

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	112.5694	2	56.2847	23.65386	2.9359E-10	3.026153
Within Groups	706.7158	297	2.379515			
Total	819.2852	299				

Appendix 4: Individual Orientational Testing Initial ANOVAs

Scallop 11

Anova: Single Factor
Resistance

SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	2459.07	245.907	125.0371
Side	10	4773.47	477.347	1647.052
End 2	10	2423.39	242.339	90.1781

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	362686.5	2	181343.3	292.1331	5.12E-19	3.354131
Within Groups	16760.4	27	620.7557			
Total	379447	29				

Anova: Single Factor
Reactance

SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	475.05	47.505	15.00092
Side	10	607.95	60.795	51.52603
End 2	10	338.44	33.844	7.503693

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	3632.011	2	1816.006	73.59138	1.17E-11	3.354131
Within Groups	666.2757	27	24.67688			
Total	4298.287	29				

	R	Xc	Z	P
HSD	27.62	5.51	27.47	0.92
End 1 - Side	-231.44	-13.29	-230.80	3.64
End 1 - End 2	3.57	13.66	5.77	2.98
Side - End 2	235.01	26.95	236.57	-0.66

Anova: Single Factor
Impedance

SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	2504.726	250.4726	129.4544
Side	10	4812.746	481.2746	1621.867
End 2	10	2447.052	244.7052	89.87268

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	364226.4	2	182113.2	296.7312	4.19E-19	3.354131
Within Groups	16570.74	27	613.7312			
Total	380797.1	29				

Anova: Single Factor
Phase Angle

SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	109.3534	10.93534	0.53189
Side	10	72.99838	7.299838	1.113351
End 2	10	79.55834	7.955834	0.433813

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	75.08234	2	37.54117	54.17058	3.54E-10	3.354131
Within Groups	18.71148	27	0.693018			
Total	93.79382	29				

Scallop 12

Anova: Single Factor
Resistance

SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	2764.95	276.495	185.9009
Side	10	3405.05	340.505	851.5994
End 2	10	2819.05	281.905	88.80492

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	25201.69	2	12600.85	33.56332	4.77E-08	3.354131
Within Groups	10136.75	27	375.4351			
Total	35338.44	29				

Anova: Single Factor
Reactance

SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	609.26	60.926	37.17107
Side	10	483.28	48.328	35.74915
End 2	10	596.56	59.656	5.909893

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	962.1536	2	481.0768	18.30811	9.45E-06	3.354131
Within Groups	709.471	27	26.27671			
Total	1671.625	29				

	R	Xc	Z	P
HSD	21.48	5.68	21.93	0.69
End 1 - Side	-64.01	12.60	-60.77	4.35
End 1 - End 2	-5.41	1.27	-5.01	0.45
Side - End 2	58.60	-11.33	55.77	-3.90

Anova: Single Factor
Impedance

SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	2831.526	283.1526	207.5899
Side	10	3439.276	343.9276	879.6659
End 2	10	2881.603	288.1603	86.80617

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	22762.18	2	11381.09	29.08132	1.84E-07	3.354131
Within Groups	10566.56	27	391.354			
Total	33328.74	29				

Anova: Single Factor
Phase Angle

SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	124.0866	12.40866	0.628697
Side	10	80.58613	8.058613	0.231006
End 2	10	119.5766	11.95766	0.313709

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	114.4296	2	57.21481	146.2781	3.25E-15	3.354131
Within Groups	10.5607	27	0.391137			
Total	124.9903	29				

Scallop 13

Anova: Single Factor
Resistance

SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	2792.33	279.233	124.0631
Side	10	3843.76	384.376	913.5154
End 2	10	2597.26	259.726	110.6113

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	89910.65	2	44955.33	117.4597	4.77E-14	3.354131
Within Groups	10333.71	27	382.7299			
Total	100244.4	29				

Anova: Single Factor
Reactance

SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	541.08	54.108	6.620618
Side	10	601.56	60.156	114.3181
End 2	10	477.46	47.746	4.768804

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	770.2048	2	385.1024	9.190437	0.000903	3.354131
Within Groups	1131.368	27	41.90251			
Total	1901.573	29				

	R	Xc	Z	P
HSD	21.69	7.18	22.31	0.82
End 1 - Side	-105.14	-6.05	-104.66	2.14
End 1 - End 2	19.51	6.36	20.35	0.55
Side - End 2	124.65	12.41	125.01	-1.59

Anova: Single Factor
Impedance

SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	2844.443	284.4443	119.7673
Side	10	3890.998	389.0998	988.9463
End 2	10	2640.932	264.0932	106.5674

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	89978.64	2	44989.32	111.0591	9.37E-14	3.354131
Within Groups	10937.53	27	405.0937			
Total	100916.2	29				

Anova: Single Factor
Phase Angle

SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	109.8172	10.98172	0.440957
Side	10	88.46485	8.846485	0.777436
End 2	10	104.3251	10.43251	0.420014

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	24.58784	2	12.29392	22.51075	1.77E-06	3.354131
Within Groups	14.74566	27	0.546136			
Total	39.3335	29				

Scallop 14

Anova: Single Factor
Resistance

SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	2618.56	261.856	169.873
Side	10	3490.36	349.036	122.4884
End 2	10	2100.47	210.047	951.8427

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	98674.89	2	49337.45	118.9615	4.09E-14	3.354131
Within Groups	11197.84	27	414.7347			
Total	109872.7	29				

Anova: Single Factor
Reactance

SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	384.35	38.435	69.33869
Side	10	445.66	44.566	10.86743
End 2	10	205.26	20.526	17.02063

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	3120.81	2	1560.405	48.1474	1.25E-09	3.354131
Within Groups	875.0407	27	32.40892			
Total	3995.851	29				

	R	Xc	Z	P
HSD	22.58	6.31	22.69	1.27
End 1 - Side	-87.18	-6.13	-87.13	1.05
End 1 - End 2	51.81	17.91	53.70	2.75
Side - End 2	138.99	24.04	140.82	1.70

Anova: Single Factor
Impedance

SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	2647.634	264.7634	179.3581
Side	10	3518.909	351.8909	116.714
End 2	10	2110.666	211.0666	959.9242

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	101020.2	2	50510.09	120.6455	3.45E-14	3.354131
Within Groups	11303.97	27	418.6654			
Total	112324.1	29				

Anova: Single Factor
Phase Angle

SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	83.34785	8.334785	2.794582
Side	10	72.89316	7.289316	0.443031
End 2	10	55.84888	5.584888	0.724026

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	38.53339	2	19.26669	14.58994	5.06E-05	3.354131
Within Groups	35.65475	27	1.320546			
Total	74.18814	29				

Scallop 15

Anova: Single Factor
Resistance

SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	2245.36	224.536	105.4522
Side	10	3096.57	309.657	577.9402
End 2	10	1838.85	183.885	67.15803

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	82388.95	2	41194.47	164.6571	7.48E-16	3.354131
Within Groups	6754.954	27	250.1835			
Total	89143.9	29				

Anova: Single Factor
Reactance

SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	407.16	40.716	7.057982
Side	10	441.67	44.167	24.82305
End 2	10	242.56	24.256	6.419893

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2264.296	2	1132.148	88.67788	1.36E-12	3.354131
Within Groups	344.7083	27	12.76697			
Total	2609.005	29				

	R	Xc	Z	P
HSD	17.54	3.96	17.79	0.61
End 1 - Side	-85.12	-3.45	-84.59	2.18
End 1 - End 2	40.65	16.46	42.73	2.78
Side - End 2	125.77	19.91	127.32	0.60

Anova: Single Factor

Anova: Single Factor
Impedance

SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	2282.106	228.2106	106.0126
Side	10	3128.01	312.801	595.8142
End 2	10	1854.852	185.4852	70.57951

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	83967.68	2	41983.84	163.0638	8.44E-16	3.354131
Within Groups	6951.657	27	257.4688			
Total	90919.34	29				

Anova: Single Factor
Phase Angle

SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	102.8652	10.28652	0.40194
Side	10	81.0723	8.10723	0.236073
End 2	10	75.02769	7.502769	0.283393

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	42.87988	2	21.43994	69.80615	2.14E-11	3.354131
Within Groups	8.292654	27	0.307135			
Total	51.17253	29				

Scallop 16

Anova: Single Factor
Resistance

SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	2676.86	267.686	120.4152
Side	10	3095.46	309.546	2767.773
End 2	10	2435.96	243.596	168.5398

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	22273.3	2	11136.65	10.92997	0.000333	3.354131
Within Groups	27510.55	27	1018.909			
Total	49783.85	29				

Anova: Single Factor
Reactance

SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	610.64	61.064	45.26418
Side	10	553.05	55.305	212.5396
End 2	10	405.96	40.596	20.90403

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2228.199	2	1114.1	11.99213	0.000188	3.354131
Within Groups	2508.37	27	92.9026			
Total	4736.569	29				

	R	Xc	Z	P
HSD	35.39	10.69	36.59	1.04
End 1 - Side	-41.86	5.76	-39.87	2.82
End 1 - End 2	24.09	20.47	27.64	3.39
Side - End 2	65.95	14.71	67.51	0.57

Anova: Single Factor
Impedance

SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	2746.161	274.6161	133.0051
Side	10	3144.832	314.4832	2955.516
End 2	10	2469.729	246.9729	179.9119

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	23037.23	2	11518.61	10.5726	0.000406	3.354131
Within Groups	29415.9	27	1089.478			
Total	52453.13	29				

Anova: Single Factor
Phase Angle

SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	128.3909	12.83909	1.403193
Side	10	100.1678	10.01678	0.706286
End 2	10	94.45105	9.445105	0.505569

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	66.03789	2	33.01894	37.87954	1.46E-08	3.354131
Within Groups	23.53543	27	0.871683			
Total	89.57332	29				

Scallop 17

Anova: Single Factor
Resistance
SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	1776.08	177.608	50.20573
Side	10	2358.28	235.828	785.3769
End 2	10	2247.69	224.769	60.79694

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	19120.1	2	9560.05	31.99554	7.53E-08	3.354131
Within Groups	8067.416	27	298.7932			
Total	27187.52	29				

Anova: Single Factor
Reactance
SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	360.85	36.085	1.707806
Side	10	334.95	33.495	3.822472
End 2	10	382.98	38.298	9.237129

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	115.5809	2	57.79046	11.74014	0.000214	3.354131
Within Groups	132.9067	27	4.922469			
Total	248.4876	29				

	R	Xc	Z	P
HSD	19.16	2.46	18.93	0.96
End 1 - Side	-58.22	2.59	-57.01	3.28
End 1 - End 2	-47.16	-2.21	-46.78	1.82
Side - End 2	11.06	-4.80	10.22	-1.46

Anova: Single Factor
Impedance
SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	1812.399	181.2399	50.62477
Side	10	2382.471	238.2471	761.5235
End 2	10	2280.24	228.024	62.16409

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	18476.95	2	9238.475	31.69968	8.23E-08	3.354131
Within Groups	7868.811	27	291.4375			
Total	26345.76	29				

Anova: Single Factor
Phase Angle
SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	114.9109	11.49109	0.127033
Side	10	82.09197	8.209197	1.612783
End 2	10	96.71005	9.671005	0.490955

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	54.06819	2	27.03409	36.35616	2.19E-08	3.354131
Within Groups	20.07694	27	0.74359			
Total	74.14513	29				

Scallop 18

Anova: Single Factor
Resistance
SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	2129.35	212.935	98.81669
Side	10	2304.24	230.424	171.2041
End 2	10	2074.35	207.435	416.4169

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2882.031	2	1441.015	6.297798	0.005691	3.354131
Within Groups	6177.939	27	228.8126			
Total	9059.97	29				

Anova: Single Factor
Reactance
SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	274.75	27.475	22.22647
Side	10	234.26	23.426	3.651071
End 2	10	192.08	19.208	36.75395

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	341.764	2	170.882	8.185116	0.001665	3.354131
Within Groups	563.6835	27	20.87716			
Total	905.4475	29				

	R	Xc	Z	P
HSD	16.77	5.07	17.04	1.18
End 1 - Side	-17.49	4.05	-16.89	1.51
End 1 - End 2	5.50	8.27	6.36	2.14
Side - End 2	22.99	4.22	23.24	0.63

Anova: Single Factor
Impedance
SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	2147.307	214.7307	106.5231
Side	10	2316.165	231.6165	172.3983
End 2	10	2083.736	208.3736	429.4883

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2885.931	2	1442.966	6.110725	0.006469	3.354131
Within Groups	6375.687	27	236.1366			
Total	9261.618	29				

Anova: Single Factor
Phase Angle
SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	73.22288	7.322288	1.076508
Side	10	58.0787	5.80787	0.151295
End 2	10	51.80884	5.180884	2.182059

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	24.24062	2	12.12031	10.66346	0.000386	3.354131
Within Groups	30.68876	27	1.136621			
Total	54.92938	29				

Scallop 19

Anova: Single Factor
Resistance
SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	2153.47	215.347	313.9589
Side	10	4156.76	415.676	2709.035
End 2	10	2233.65	223.365	112.3256

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	257265.1	2	128632.5	123.0808	2.7E-14	3.354131
Within Groups	28217.87	27	1045.106			
Total	285482.9	29				

Anova: Single Factor
Reactance
SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	404.48	40.448	30.3248
Side	10	802.87	80.287	141.1954
End 2	10	368.78	36.878	12.55882

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	11614.11	2	5807.054	94.63958	6.32E-13	3.354131
Within Groups	1656.711	27	61.35967			
Total	13270.82	29				

	R	Xc	Z	P
HSD	35.84	8.68	36.72	0.74
End 1 - Side	-200.33	-39.84	-204.24	-0.30
End 1 - End 2	-8.02	3.57	-7.26	1.25
Side - End 2	192.31	43.41	196.97	1.55

Anova: Single Factor
Impedance
SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	2191.346	219.1346	333.5935
Side	10	4233.725	423.3725	2837.184
End 2	10	2263.99	226.399	119.7559

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	268548.1	2	134274	122.4185	2.89E-14	3.354131
Within Groups	29614.8	27	1096.844			
Total	298162.9	29				

Anova: Single Factor
Phase Angle
SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	106.097	10.6097	0.774239
Side	10	109.1306	10.91306	0.239173
End 2	10	93.62706	9.362706	0.326109

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	13.50203	2	6.751015	15.11962	3.93E-05	3.354131
Within Groups	12.05569	27	0.446507			
Total	25.55772	29				

Scallop 20

Anova: Single Factor
Resistance
SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	2612.45	261.245	280.2418
Side	10	2965.25	296.525	145.2747
End 2	10	2439	243.9	218.8378

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	14383.06	2	7191.53	33.4825	4.88E-08	3.354131
Within Groups	5799.189	27	214.7848			
Total	20182.25	29				

Anova: Single Factor
Reactance
SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	535.75	53.575	27.17647
Side	10	379.85	37.985	15.06558
End 2	10	459.24	45.924	38.60143

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1215.379	2	607.6894	22.55059	1.74E-06	3.354131
Within Groups	727.5913	27	26.94783			
Total	1942.97	29				

	R	Xc	Z	P
HSD	16.25	5.76	16.82	0.82
End 1 - Side	-35.28	15.59	-32.28	4.27
End 1 - End 2	17.35	7.65	18.47	0.94
Side - End 2	52.63	-7.94	50.75	-3.33

Anova: Single Factor
Impedance
SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	2666.903	266.6903	302.418
Side	10	2989.681	298.9681	146.9885
End 2	10	2482.161	248.2161	240.7674

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	13196.42	2	6598.21	28.68064	2.09E-07	3.354131
Within Groups	6211.565	27	230.058			
Total	19407.98	29				

Anova: Single Factor
Phase Angle
SUMMARY

Groups	Count	Sum	Average	Variance
End 1	10	115.7191	11.57191	0.223831
Side	10	73.01143	7.301143	0.500163
End 2	10	106.2719	10.62719	0.921756

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	100.6482	2	50.32412	91.73471	9.13E-13	3.354131
Within Groups	14.81175	27	0.548583			
Total	115.46	29				

Appendix 5: Normalized Orientational Testing Secondary ANOVAs

Anova: Single Factor
Resistance
SUMMARY

Groups	Count	Sum	Average	Variance
End 1	100	480.0738	4.800738	1.019812
Side	100	664.8298	6.648298	3.537599
End 2	100	461.2884	4.612884	1.053641

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	253.0558	2	126.5279	67.6493	6.1721E-25	3.026153
Within Groups	555.4942	297	1.870351			
Total	808.55	299				

HSD	0.46
End 1 - Side	-1.85
End 1 - End 2	0.19
Side - End 2	2.04

Anova: Single Factor
Reactance
SUMMARY

Groups	Count	Sum	Average	Variance
End 1	100	92.1664	0.921664	0.092883
Side	100	97.30247	0.973025	0.136878
End 2	100	74.29696	0.74297	0.107986

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2.916499	2	1.458249	12.95278	4.0422E-06	3.026153
Within Groups	33.43685	297	0.112582			
Total	36.35335	299				

HSD	0.11
End 1 - Side	-0.05
End 1 - End 2	0.18
Side - End 2	0.23

Anova: Single Factor
Impedance
SUMMARY

Groups	Count	Sum	Average	Variance
End 1	100	489.0786	4.890786	1.089213
Side	100	672.166	6.72166	3.640059
End 2	100	467.5666	4.675666	1.130163

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	252.8155	2	126.4078	64.72009	4.6817E-24	3.026153
Within Groups	580.0842	297	1.953145			
Total	832.8997	299				

HSD	0.47
End 1 - Side	-1.83
End 1 - End 2	0.22
Side - End 2	2.05

Anova: Single Factor
Phase Angle
SUMMARY

Groups	Count	Sum	Average	Variance
End 1	100	1067.811	10.67811	3.409708
Side	100	818.4953	8.184953	2.493449
End 2	100	877.2055	8.772055	4.972707

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	339.7857	2	169.8929	46.86328	2.0474E-18	3.026153
Within Groups	1076.711	297	3.625288			
Total	1416.496	299				

HSD	0.63
End 1 - Side	2.49
End 1 - End 2	1.91
Side - End 2	-0.59

Appendix 6: Individual Effect of Freezing Testing Initial ANOVAs

Scallop 21

Anova: Single Factor

Resistance (R)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2561.66	256.166	96.88432
Frozen (12 hrs)	10	2103.98	210.398	24.41202
Frozen (24 hrs)	10	1339.35	133.935	74.19514

HSD	8.949838
Fresh - Frozen (12hrs)	45.768
Fresh - Frozen (24 hrs)	122.231
Frozen (12hrs) - Frozen (24hrs)	76.463

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	76272.39	2	38136.2	585.2357	5.846E-23	3.354131
Within Groups	1759.423	27	65.16382			
Total	78031.82	29				

Anova: Single Factor

Imedance (Z)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2580.017	258.0017	91.44437
Frozen (12 hrs)	10	2150.299	215.0299	23.07691
Frozen (24 hrs)	10	1349.305	134.9305	74.85715

HSD	8.808796
Fresh - Frozen (12hrs)	42.97179
Fresh - Frozen (24 hrs)	123.0712
Frozen (12hrs) - Frozen (24hrs)	80.09941

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	78030.03	2	39015.01	618.0484	2.845E-23	3.354131
Within Groups	1704.406	27	63.12614			
Total	79734.43	29				

Anova: Single Factor

Reactance (X)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	305.46	30.546	6.53636
Frozen (12 hrs)	10	443.76	44.376	0.107404
Frozen (24 hrs)	10	163.56	16.356	0.804116

HSD	1.746898
Fresh - Frozen (12hrs)	-13.83
Fresh - Frozen (24 hrs)	14.19
Frozen (12hrs) - Frozen (24hrs)	28.02

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	3925.818	2	1962.909	790.6581	1.09E-24	3.354131
Within Groups	67.03092	27	2.482627			
Total	3992.849	29				

Anova: Single Factor

Phase Angle (P)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	68.22312	6.822312	0.584672
Frozen (12 hrs)	10	119.1699	11.91699	0.099637
Frozen (24 hrs)	10	69.68035	6.968035	0.02421

HSD	0.538799
Fresh - Frozen (12hrs)	-5.09467
Fresh - Frozen (24 hrs)	-0.14572
Frozen (12hrs) - Frozen (24hrs)	4.948951

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	168.2302	2	84.1151	356.1591	3.928E-20	3.354131
Within Groups	6.376666	27	0.236173			
Total	174.6069	29				

Scallop 22

Anova: Single Factor

Resistance (R)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2536.86	253.686	83.50316
Frozen (12 hrs)	10	2403.94	240.394	42.53247
Frozen (24 hrs)	10	1611.48	161.148	47.53213

HSD	8.433072
Fresh - Frozen (12hrs)	13.292
Fresh - Frozen (24 hrs)	92.538
Frozen (12hrs) - Frozen (24hrs)	79.246

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	50066.29	2	25033.15	432.6808	3.098E-21	3.354131
Within Groups	1562.11	27	57.85592			
Total	51628.4	29				

Anova: Single Factor

Imedance (Z)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2575.919	257.5919	81.01616
Frozen (12 hrs)	10	2465.764	246.5764	38.38497
Frozen (24 hrs)	10	1620.524	162.0524	46.00694

HSD	8.23246
Fresh - Frozen (12hrs)	11.01553
Fresh - Frozen (24 hrs)	95.53953
Frozen (12hrs) - Frozen (24hrs)	84.524

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	54644.84	2	27322.42	495.5457	5.227E-22	3.354131
Within Groups	1488.673	27	55.13603			
Total	56133.51	29				

Anova: Single Factor

Reactance (X)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	446.57	44.657	0.57709
Frozen (12 hrs)	10	548.26	54.826	1.126849
Frozen (24 hrs)	10	170.38	17.038	0.699751

HSD	0.992409
Fresh - Frozen (12hrs)	-10.169
Fresh - Frozen (24 hrs)	27.619
Frozen (12hrs) - Frozen (24hrs)	37.788

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	7647.169	2	3823.584	4772.143	3.805E-35	3.354131
Within Groups	21.63321	27	0.80123			
Total	7668.802	29				

Anova: Single Factor

Phase Angle (P)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	99.95307	9.995307	0.147606
Frozen (12 hrs)	10	128.5968	12.85968	0.279435
Frozen (24 hrs)	10	60.54871	6.054871	0.273864

HSD	0.535896
Fresh - Frozen (12hrs)	-2.86437
Fresh - Frozen (24 hrs)	3.940436
Frozen (12hrs) - Frozen (24hrs)	6.804805

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	233.4567	2	116.7284	499.6183	4.694E-22	3.354131
Within Groups	6.308146	27	0.233635			
Total	239.7648	29				

Scallop 23

Anova: Single Factor

Resistance (R)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2084.85	208.485	42.00003
Frozen (12 hrs)	10	2719.25	271.925	77.99403
Frozen (24 hrs)	10	1701.26	170.126	14.07352

HSD	7.41162
Fresh - Frozen (12hrs)	-63.44
Fresh - Frozen (24 hrs)	38.359
Frozen (12hrs) - Frozen (24hrs)	101.799

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	52863.61	2	26431.8	591.4586	5.084E-23	3.354131
Within Groups	1206.608	27	44.68919			
Total	54070.22	29				

Anova: Single Factor

Impedance (Z)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2101.51	210.151	38.85212
Frozen (12 hrs)	10	2800.361	280.0361	71.64847
Frozen (24 hrs)	10	1715.259	171.5259	12.75059

HSD	7.106354
Fresh - Frozen (12hrs)	-69.8851
Fresh - Frozen (24 hrs)	38.62513
Frozen (12hrs) - Frozen (24hrs)	108.5102

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	60500.97	2	30250.48	736.313	2.803E-24	3.354131
Within Groups	1109.261	27	41.08373			
Total	61610.23	29				

Anova: Single Factor

Reactance (X)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	263.04	26.304	3.015827
Frozen (12 hrs)	10	668.65	66.865	0.399139
Frozen (24 hrs)	10	218.06	21.806	1.750671

HSD	1.454833
Fresh - Frozen (12hrs)	-40.561
Fresh - Frozen (24 hrs)	4.498
Frozen (12hrs) - Frozen (24hrs)	45.059

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	12319.13	2	6159.567	3577.236	1.839E-33	3.354131
Within Groups	46.49073	27	1.721879			
Total	12365.62	29				

Anova: Single Factor

Phase Angle (P)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	72.08868	7.208868	0.44788
Frozen (12 hrs)	10	138.2972	13.82972	0.269012
Frozen (24 hrs)	10	73.15135	7.315135	0.335143

HSD	0.656548
Fresh - Frozen (12hrs)	-6.62085
Fresh - Frozen (24 hrs)	-0.10627
Frozen (12hrs) - Frozen (24hrs)	6.514585

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	287.6226	2	143.8113	410.0942	6.247E-21	3.354131
Within Groups	9.468324	27	0.350679			
Total	297.0909	29				

Scallop 24

Anova: Single Factor

Resistance (R)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2252.07	225.207	50.20731
Frozen (12 hrs)	10	2365.45	236.545	20.73581
Frozen (24 hrs)	10	1392.67	139.267	13.82838

HSD	5.89354
Fresh - Frozen (12hrs)	-11.338
Fresh - Frozen (24 hrs)	85.94
Frozen (12hrs) - Frozen (24hrs)	97.278

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	56590.81	2	28295.41	1001.353	4.71E-26	3.354131
Within Groups	762.9435	27	28.25717			
Total	57353.75	29				

Anova: Single Factor

Imedance (Z)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2259.946	225.9946	46.38625
Frozen (12 hrs)	10	2418.489	241.8489	20.08082
Frozen (24 hrs)	10	1398.775	139.8775	13.61519

HSD	5.728217
Fresh - Frozen (12hrs)	-15.8542
Fresh - Frozen (24 hrs)	86.11711
Frozen (12hrs) - Frozen (24hrs)	101.9713

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	60218.89	2	30109.44	1127.944	9.635E-27	3.354131
Within Groups	720.7404	27	26.69409			
Total	60939.63	29				

Anova: Single Factor

Reactance (X)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	184.67	18.467	12.11882
Frozen (12 hrs)	10	503.65	50.365	0.118472
Frozen (24 hrs)	10	130.46	13.046	0.034582

HSD	2.242368
Fresh - Frozen (12hrs)	-31.898
Fresh - Frozen (24 hrs)	5.421
Frozen (12hrs) - Frozen (24hrs)	37.319

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	8131.925	2	4065.962	993.9707	5.198E-26	3.354131
Within Groups	110.4469	27	4.090626			
Total	8242.372	29				

Anova: Single Factor

Phase Angle (P)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	47.15013	4.715013	1.00041
Frozen (12 hrs)	10	120.2397	12.02397	0.04237
Frozen (24 hrs)	10	53.56678	5.356678	0.040842

HSD	0.666332
Fresh - Frozen (12hrs)	-7.30896
Fresh - Frozen (24 hrs)	-0.64167
Frozen (12hrs) - Frozen (24hrs)	6.667295

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	327.6182	2	163.8091	453.504	1.674E-21	3.354131
Within Groups	9.752606	27	0.361208			
Total	337.3708	29				

Scallop 25

Anova: Single Factor

Resistance (R)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2338.76	233.876	83.31918
Frozen (12 hrs)	10	2215.63	221.563	683.9657
Frozen (24 hrs)	10	1189.96	118.996	2.130693

HSD	17.75545
Fresh - Frozen (12hrs)	12.313
Fresh - Frozen (24 hrs)	114.88
Frozen (12hrs) - Frozen (24hrs)	102.567

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	79563.38	2	39781.69	155.1113	1.572E-15	3.354131
Within Groups	6924.74	27	256.4718			
Total	86488.12	29				

Anova: Single Factor

Imedance (Z)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2344.714	234.4714	79.13006
Frozen (12 hrs)	10	2271.918	227.1918	682.8291
Frozen (24 hrs)	10	1197.22	119.722	2.230338

HSD	17.69505
Fresh - Frozen (12hrs)	7.279524
Fresh - Frozen (24 hrs)	114.7493
Frozen (12hrs) - Frozen (24hrs)	107.4698

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	82567.16	2	41283.58	162.0681	9.109E-16	3.354131
Within Groups	6877.706	27	254.7298			
Total	89444.87	29				

Anova: Single Factor

Reactance (X)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	162.25	16.225	13.12425
Frozen (12 hrs)	10	501.4	50.14	12.136
Frozen (24 hrs)	10	131.58	13.158	0.308284

HSD	3.236713
Fresh - Frozen (12hrs)	-33.915
Fresh - Frozen (24 hrs)	3.067
Frozen (12hrs) - Frozen (24hrs)	36.982

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	8424.34	2	4212.17	494.2211	5.415E-22	3.354131
Within Groups	230.1168	27	8.522845			
Total	8654.457	29				

Anova: Single Factor

Phase Angle (P)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	40.02053	4.002053	1.001456
Frozen (12 hrs)	10	128.3893	12.83893	0.908992
Frozen (24 hrs)	10	63.09088	6.309088	0.04768

HSD	0.895719
Fresh - Frozen (12hrs)	-8.83688
Fresh - Frozen (24 hrs)	-2.30704
Frozen (12hrs) - Frozen (24hrs)	6.529844

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	420.1724	2	210.0862	321.8679	1.462E-19	3.354131
Within Groups	17.62315	27	0.652709			
Total	437.7956	29				

Scallop 26

Anova: Single Factor

Resistance (R)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2481.65	248.165	84.04025
Frozen (12 hrs)	10	2072.03	207.203	6.193846
Frozen (24 hrs)	10	1238.18	123.818	13.30788

HSD	6.513427
Fresh - Frozen (12hrs)	40.962
Fresh - Frozen (24 hrs)	124.347
Frozen (12hrs) - Frozen (24hrs)	83.385

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	80310.4	2	40155.2	1163.447	6.372E-27	3.354131
Within Groups	931.8778	27	34.51399			
Total	81242.28	29				

Anova: Single Factor

Imedance (Z)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2507.768	250.7768	78.44755
Frozen (12 hrs)	10	2104.094	210.4094	5.651206
Frozen (24 hrs)	10	1243.583	124.3583	13.20133

HSD	6.314048
Fresh - Frozen (12hrs)	40.3674
Fresh - Frozen (24 hrs)	126.4185
Frozen (12hrs) - Frozen (24hrs)	86.05113

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	83386.56	2	41693.28	1285.506	1.682E-27	3.354131
Within Groups	875.7008	27	32.43336			
Total	84262.26	29				

Anova: Single Factor

Reactance (X)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	359.96	35.996	2.682249
Frozen (12 hrs)	10	365.78	36.578	0.679707
Frozen (24 hrs)	10	115.75	11.575	0.018917

HSD	1.176971
Fresh - Frozen (12hrs)	-0.582
Fresh - Frozen (24 hrs)	24.421
Frozen (12hrs) - Frozen (24hrs)	25.003

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4072.913	2	2036.457	1807.04	1.765E-29	3.354131
Within Groups	30.42785	27	1.126957			
Total	4103.341	29				

Anova: Single Factor

Phase Angle (P)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	82.74169	8.274169	0.423758
Frozen (12 hrs)	10	100.1445	10.01445	0.090656
Frozen (24 hrs)	10	53.45069	5.345069	0.026212

HSD	0.470652
Fresh - Frozen (12hrs)	-1.74028
Fresh - Frozen (24 hrs)	2.9291
Frozen (12hrs) - Frozen (24hrs)	4.669382

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	111.3711	2	55.68556	309.0062	2.479E-19	3.354131
Within Groups	4.865631	27	0.180209			
Total	116.2368	29				

Scallop 27

Anova: Single Factor

Resistance (R)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	1892.35	189.235	53.04114
Frozen (12 hrs)	10	2448.95	244.895	2.929806
Frozen (24 hrs)	10	1434.24	143.424	2.015649

HSD	4.874332
Fresh - Frozen (12hrs)	-55.66
Fresh - Frozen (24 hrs)	45.811
Frozen (12hrs) - Frozen (24hrs)	101.471

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	51643.49	2	25821.75	1335.916	1.006E-27	3.354131
Within Groups	521.8793	27	19.32886			
Total	52165.37	29				

Anova: Single Factor

Imedance (Z)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	1906.113	190.6113	48.75451
Frozen (12 hrs)	10	2523.078	252.3078	2.445728
Frozen (24 hrs)	10	1444.374	144.4374	1.956084

HSD	4.666903
Fresh - Frozen (12hrs)	-61.6965
Fresh - Frozen (24 hrs)	46.17387
Frozen (12hrs) - Frozen (24hrs)	107.8704

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	58581.67	2	29290.83	1653.096	5.818E-29	3.354131
Within Groups	478.4069	27	17.71877			
Total	59060.08	29				

Anova: Single Factor

Reactance (X)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	226.55	22.655	6.300694
Frozen (12 hrs)	10	606.96	60.696	1.35336
Frozen (24 hrs)	10	170.78	17.078	0.013707

HSD	1.772497
Fresh - Frozen (12hrs)	-38.041
Fresh - Frozen (24 hrs)	5.577
Frozen (12hrs) - Frozen (24hrs)	43.618

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	11269.17	2	5634.584	2204.523	1.227E-30	3.354131
Within Groups	69.00985	27	2.55592			
Total	11338.18	29				

Anova: Single Factor

Phase Angle (P)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	68.58473	6.858473	0.901013
Frozen (12 hrs)	10	139.219	13.9219	0.094353
Frozen (24 hrs)	10	67.91841	6.791841	0.011449

HSD	0.642283
Fresh - Frozen (12hrs)	-7.06343
Fresh - Frozen (24 hrs)	0.066631
Frozen (12hrs) - Frozen (24hrs)	7.130062

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	335.7809	2	167.8904	500.262	4.616E-22	3.354131
Within Groups	9.061335	27	0.335605			
Total	344.8422	29				

Scallop 28

Anova: Single Factor

Resistance (R)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2816.37	281.637	28.28496
Frozen (12 hrs)	10	2474.77	247.477	17.21567
Frozen (24 hrs)	10	1582.96	158.296	39.2718

HSD	5.893572
Fresh - Frozen (12hrs)	34.16
Fresh - Frozen (24 hrs)	123.341
Frozen (12hrs) - Frozen (24hrs)	89.181

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	81110.53	2	40555.26	1435.205	3.857E-28	3.354131
Within Groups	762.9519	27	28.25748			
Total	81873.48	29				

Anova: Single Factor

Imedance (Z)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2855.208	285.5208	25.66307
Frozen (12 hrs)	10	2525.361	252.5361	13.62473
Frozen (24 hrs)	10	1591.193	159.1193	37.02004

HSD	5.591597
Fresh - Frozen (12hrs)	32.9847
Fresh - Frozen (24 hrs)	126.4015
Frozen (12hrs) - Frozen (24hrs)	93.41675

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	85973.36	2	42986.68	1689.997	4.329E-29	3.354131
Within Groups	686.7706	27	25.43595			
Total	86660.13	29				

Anova: Single Factor

Reactance (X)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	468.96	46.896	1.232027
Frozen (12 hrs)	10	502.17	50.217	5.128823
Frozen (24 hrs)	10	160.28	16.028	2.673151

HSD	1.923939
Fresh - Frozen (12hrs)	-3.321
Fresh - Frozen (24 hrs)	30.868
Frozen (12hrs) - Frozen (24hrs)	34.189

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	7109.167	2	3554.584	1180.402	5.253E-27	3.354131
Within Groups	81.30601	27	3.011334			
Total	7190.473	29				

Anova: Single Factor

Phase Angle (P)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	94.60676	9.460676	0.155972
Frozen (12 hrs)	10	114.7943	11.47943	0.439059
Frozen (24 hrs)	10	58.08869	5.808869	0.625258

HSD	0.707103
Fresh - Frozen (12hrs)	-2.01875
Fresh - Frozen (24 hrs)	3.651807
Frozen (12hrs) - Frozen (24hrs)	5.670557

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	165.2209	2	82.61044	203.0922	5.35E-17	3.354131
Within Groups	10.98261	27	0.406763			
Total	176.2035	29				

Scallop 29

Anova: Single Factor

Resistance (R)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2901.86	290.186	98.2196
Frozen (12 hrs)	10	2163.82	216.382	36.34084
Frozen (24 hrs)	10	1600.06	160.006	23.83512

HSD	8.056062
Fresh - Frozen (12hrs)	73.804
Fresh - Frozen (24 hrs)	130.18
Frozen (12hrs) - Frozen (24hrs)	56.376

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	85240.39	2	42620.19	807.2233	8.277E-25	3.354131
Within Groups	1425.56	27	52.79852			
Total	86665.95	29				

Anova: Single Factor

Imedance (Z)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2944.613	294.4613	89.04341
Frozen (12 hrs)	10	2190.678	219.0678	34.1592
Frozen (24 hrs)	10	1610.992	161.0992	23.1771

HSD	7.74447
Fresh - Frozen (12hrs)	75.39351
Fresh - Frozen (24 hrs)	133.3622
Frozen (12hrs) - Frozen (24hrs)	57.96867

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	89433.39	2	44716.7	916.4528	1.532E-25	3.354131
Within Groups	1317.417	27	48.79324			
Total	90750.81	29				

Anova: Single Factor

Reactance (X)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	498.75	49.875	4.210694
Frozen (12 hrs)	10	341.54	34.154	1.203938
Frozen (24 hrs)	10	187.17	18.717	0.112157

HSD	1.504831
Fresh - Frozen (12hrs)	15.721
Fresh - Frozen (24 hrs)	31.158
Frozen (12hrs) - Frozen (24hrs)	15.437

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4854.239	2	2427.12	1317.466	1.211E-27	3.354131
Within Groups	49.7411	27	1.842263			
Total	4903.98	29				

Anova: Single Factor

Phase Angle (P)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	97.73259	9.773259	0.50019
Frozen (12 hrs)	10	89.80609	8.980609	0.229898
Frozen (24 hrs)	10	66.80656	6.680656	0.095276

HSD	0.581533
Fresh - Frozen (12hrs)	0.79265
Fresh - Frozen (24 hrs)	3.092603
Frozen (12hrs) - Frozen (24hrs)	2.299954

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	51.60759	2	25.80379	93.79053	7.03E-13	3.354131
Within Groups	7.428281	27	0.275122			
Total	59.03587	29				

Scallop 30

Anova: Single Factor
Resistance (R)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2568.37	256.837	6.158734
Frozen (12 hrs)	10	2192.49	219.249	52.73734
Frozen (24 hrs)	10	1502.06	150.206	28.88867

HSD	5.99737
Fresh - Frozen (12hrs)	37.588
Fresh - Frozen (24 hrs)	106.631
Frozen (12hrs) - Frozen (24hrs)	69.043

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	58499.88	2	29249.94	999.6021	4.822E-26	3.354131
Within Groups	790.0627	27	29.26158			
Total	59289.94	29				

Anova: Single Factor
Imedance (Z)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2586.492	258.6492	5.211902
Frozen (12 hrs)	10	2229.057	222.9057	50.46075
Frozen (24 hrs)	10	1513.896	151.3896	27.32652

HSD	5.831606
Fresh - Frozen (12hrs)	35.74355
Fresh - Frozen (24 hrs)	107.2596
Frozen (12hrs) - Frozen (24hrs)	71.51602

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	59655.86	2	29827.93	1078.129	1.76E-26	3.354131
Within Groups	746.9926	27	27.66639			
Total	60402.85	29				

Anova: Single Factor
Reactance (X)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	305.07	30.507	2.931757
Frozen (12 hrs)	10	401.77	40.177	0.631001
Frozen (24 hrs)	10	188.3	18.83	1.117889

HSD	1.384855
Fresh - Frozen (12hrs)	-9.67
Fresh - Frozen (24 hrs)	11.677
Frozen (12hrs) - Frozen (24hrs)	21.347

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2285.185	2	1142.593	732.33	3.012E-24	3.354131
Within Groups	42.12582	27	1.560216			
Total	2327.311	29				

Anova: Single Factor
Phase Angle (P)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	67.77469	6.777469	0.191095
Frozen (12 hrs)	10	103.9604	10.39604	0.182963
Frozen (24 hrs)	10	71.63829	7.163829	0.379335

HSD	0.5556
Fresh - Frozen (12hrs)	-3.61857
Fresh - Frozen (24 hrs)	-0.38636
Frozen (12hrs) - Frozen (24hrs)	3.232209

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	78.96832	2	39.48416	157.2252	1.329E-15	3.354131
Within Groups	6.780544	27	0.251131			
Total	85.74887	29				

Scallop 31

Anova: Single Factor
Resistance (R)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2161.88	216.188	36.01897
Frozen (12 hrs)	10	2531.26	253.126	93.41863
Frozen (24 hrs)	10	1820.17	182.017	49.20616

HSD	8.555496
Fresh - Frozen (12hrs)	-36.938
Fresh - Frozen (24 hrs)	34.171
Frozen (12hrs) - Frozen (24hrs)	71.109

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	25295.21	2	12647.6	212.3937	3.032E-17	3.354131
Within Groups	1607.794	27	59.54792			
Total	26903	29				

Anova: Single Factor
Imedance (Z)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2172.466	217.2466	32.86786
Frozen (12 hrs)	10	2556.324	255.6324	82.4297
Frozen (24 hrs)	10	1828.998	182.8998	47.98118

HSD	8.179299
Fresh - Frozen (12hrs)	-38.3858
Fresh - Frozen (24 hrs)	34.34674
Frozen (12hrs) - Frozen (24hrs)	72.73258

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	26477.33	2	13238.66	243.2405	5.387E-18	3.354131
Within Groups	1469.509	27	54.42625			
Total	27946.84	29				

Anova: Single Factor
Reactance (X)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	212.15	21.215	6.566917
Frozen (12 hrs)	10	353.87	35.387	14.47629
Frozen (24 hrs)	10	179.07	17.907	0.442423

HSD	2.967053
Fresh - Frozen (12hrs)	-14.172
Fresh - Frozen (24 hrs)	3.308
Frozen (12hrs) - Frozen (24hrs)	17.48

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1724.463	2	862.2314	120.3918	3.534E-14	3.354131
Within Groups	193.3707	27	7.161877			
Total	1917.833	29				

Anova: Single Factor
Phase Angle (P)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	56.24414	5.624414	0.668502
Frozen (12 hrs)	10	79.94639	7.994639	1.252045
Frozen (24 hrs)	10	56.32307	5.632307	0.155746

HSD	0.92235
Fresh - Frozen (12hrs)	-2.37023
Fresh - Frozen (24 hrs)	-0.00789
Frozen (12hrs) - Frozen (24hrs)	2.362332

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	37.3288	2	18.6644	26.96787	3.66E-07	3.354131
Within Groups	18.68664	27	0.692098			
Total	56.01544	29				

Scallop 32

Anova: Single Factor
Resistance (R)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2067.75	206.775	17.02536
Frozen (12 hrs)	10	2331.45	233.145	12.30136
Frozen (24 hrs)	10	1563.37	156.337	2.76429

HSD	3.626127
Fresh - Frozen (12hrs)	-26.37
Fresh - Frozen (24 hrs)	50.438
Frozen (12hrs) - Frozen (24hrs)	76.808

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	30462.79	2	15231.4	1423.894	4.288E-28	3.354131
Within Groups	288.8191	27	10.697			
Total	30751.61	29				

Anova: Single Factor
Imedance (Z)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2075.717	207.5717	15.53715
Frozen (12 hrs)	10	2408.245	240.8245	11.47914
Frozen (24 hrs)	10	1576.546	157.6546	2.746174

HSD	3.492092
Fresh - Frozen (12hrs)	-33.2528
Fresh - Frozen (24 hrs)	49.91718
Frozen (12hrs) - Frozen (24hrs)	83.16996

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	35049.05	2	17524.52	1766.439	2.394E-29	3.354131
Within Groups	267.8622	27	9.920821			
Total	35316.91	29				

Anova: Single Factor
Reactance (X)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	179.67	17.967	6.633046
Frozen (12 hrs)	10	603.24	60.324	0.143427
Frozen (24 hrs)	10	203.38	20.338	0.055973

HSD	1.673167
Fresh - Frozen (12hrs)	-42.357
Fresh - Frozen (24 hrs)	-2.371
Frozen (12hrs) - Frozen (24hrs)	39.986

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	11328.72	2	5664.362	2487.116	2.431E-31	3.354131
Within Groups	61.49201	27	2.277482			
Total	11390.22	29				

Anova: Single Factor
Phase Angle (P)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	49.78601	4.978601	0.600723
Frozen (12 hrs)	10	145.1034	14.51034	0.053688
Frozen (24 hrs)	10	74.13073	7.413073	0.009798

HSD	0.52168
Fresh - Frozen (12hrs)	-9.53174
Fresh - Frozen (24 hrs)	-2.43447
Frozen (12hrs) - Frozen (24hrs)	7.097264

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	490.506	2	245.253	1107.721	1.227E-26	3.354131
Within Groups	5.977885	27	0.221403			
Total	496.4839	29				

Scallop 33

Anova: Single Factor
Resistance (R)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2977.65	297.765	23.11381
Frozen (12 hrs)	10	1964.26	196.426	28.95796
Frozen (24 hrs)	10	1323.63	132.363	2.154779

HSD	4.713649
Fresh - Frozen (12hrs)	101.339
Fresh - Frozen (24 hrs)	165.402
Frozen (12hrs) - Frozen (24hrs)	64.063

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	139104.9	2	69552.47	3847.883	6.894E-34	3.354131
Within Groups	488.0389	27	18.07551			
Total	139593	29				

Anova: Single Factor
Imedance (Z)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	3078.229	307.8229	14.54042
Frozen (12 hrs)	10	2002.415	200.2415	24.90209
Frozen (24 hrs)	10	1330.459	133.0459	2.249776

HSD	4.133131
Fresh - Frozen (12hrs)	107.5814
Fresh - Frozen (24 hrs)	174.7769
Frozen (12hrs) - Frozen (24hrs)	67.19553

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	155453.2	2	77726.62	5592.877	4.491E-36	3.354131
Within Groups	375.2306	27	13.89743			
Total	155828.5	29				

Anova: Single Factor
Reactance (X)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	779.16	77.916	13.67554
Frozen (12 hrs)	10	388.17	38.817	3.405046
Frozen (24 hrs)	10	134.35	13.435	0.940472

HSD	2.717324
Fresh - Frozen (12hrs)	39.099
Fresh - Frozen (24 hrs)	64.481
Frozen (12hrs) - Frozen (24hrs)	25.382

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	21102.59	2	10551.3	1756.495	2.582E-29	3.354131
Within Groups	162.1895	27	6.007019			
Total	21264.78	29				

Anova: Single Factor
Phase Angle (P)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	146.7397	14.67397	0.764626
Frozen (12 hrs)	10	111.9561	11.19561	0.595328
Frozen (24 hrs)	10	57.95048	5.795048	0.15626

HSD	0.788191
Fresh - Frozen (12hrs)	3.478363
Fresh - Frozen (24 hrs)	8.878922
Frozen (12hrs) - Frozen (24hrs)	5.400559

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	400.3344	2	200.1672	396.0532	9.847E-21	3.354131
Within Groups	13.64593	27	0.505405			
Total	413.9803	29				

Scallop 34

Anova: Single Factor
Resistance (R)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2304.46	230.446	19.49903
Frozen (12 hrs)	10	2172.35	217.235	9.390472
Frozen (24 hrs)	10	1548.16	154.816	8.715316

HSD	3.925301
Fresh - Frozen (12hrs)	13.211
Fresh - Frozen (24 hrs)	75.63
Frozen (12hrs) - Frozen (24hrs)	62.419

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	32635.2	2	16317.6	1301.769	1.422E-27	3.354131
Within Groups	338.4433	27	12.53494			
Total	32973.64	29				

Anova: Single Factor
Imedance (Z)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2338.167	233.8167	16.67756
Frozen (12 hrs)	10	2219.133	221.9133	8.522113
Frozen (24 hrs)	10	1558.411	155.8411	8.461163

HSD	3.713759
Fresh - Frozen (12hrs)	11.90341
Fresh - Frozen (24 hrs)	77.97559
Frozen (12hrs) - Frozen (24hrs)	66.07218

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	35291.39	2	17645.7	1572.661	1.135E-28	3.354131
Within Groups	302.9475	27	11.22028			
Total	35594.34	29				

Anova: Single Factor
Reactance (X)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	394.96	39.496	2.696471
Frozen (12 hrs)	10	453.15	45.315	0.269583
Frozen (24 hrs)	10	178.34	17.834	0.204116

HSD	1.139705
Fresh - Frozen (12hrs)	-5.819
Fresh - Frozen (24 hrs)	21.662
Frozen (12hrs) - Frozen (24hrs)	27.481

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4194.361	2	2097.181	1984.607	5.025E-30	3.354131
Within Groups	28.53153	27	1.056723			
Total	4222.893	29				

Anova: Single Factor
Phase Angle (P)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	97.35046	9.735046	0.330273
Frozen (12 hrs)	10	117.8682	11.78682	0.074754
Frozen (24 hrs)	10	65.75032	6.575032	0.062425

HSD	0.437643
Fresh - Frozen (12hrs)	-2.05178
Fresh - Frozen (24 hrs)	3.160013
Frozen (12hrs) - Frozen (24hrs)	5.21179

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	137.8608	2	68.93038	442.3795	2.318E-21	3.354131
Within Groups	4.207067	27	0.155817			
Total	142.0678	29				

Scallop 35

Anova: Single Factor
Resistance (R)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2458.78	245.878	12.25704
Frozen (12 hrs)	10	2412.09	241.209	51.92548
Frozen (24 hrs)	10	1583.35	158.335	25.44447

HSD	6.059973
Fresh - Frozen (12hrs)	4.669
Fresh - Frozen (24 hrs)	87.543
Frozen (12hrs) - Frozen (24hrs)	82.874

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	48512.25	2	24256.13	811.9026	7.665E-25	3.354131
Within Groups	806.6429	27	29.87566			
Total	49318.9	29				

Anova: Single Factor
Imedance (Z)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2505.065	250.5065	9.403653
Frozen (12 hrs)	10	2471.128	247.1128	49.35642
Frozen (24 hrs)	10	1596.279	159.6279	24.49459

HSD	5.840575
Fresh - Frozen (12hrs)	3.393739
Fresh - Frozen (24 hrs)	90.87868
Frozen (12hrs) - Frozen (24hrs)	87.48494

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	53080.22	2	26540.11	956.3468	8.69E-26	3.354131
Within Groups	749.292	27	27.75156			
Total	53829.52	29				

Anova: Single Factor
Reactance (X)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	478.65	47.865	4.344917
Frozen (12 hrs)	10	536.64	53.664	0.909516
Frozen (24 hrs)	10	202.47	20.247	0.317801

HSD	1.511005
Fresh - Frozen (12hrs)	-5.799
Fresh - Frozen (24 hrs)	27.618
Frozen (12hrs) - Frozen (24hrs)	33.417

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	6376.927	2	3188.464	1716.617	3.511E-29	3.354131
Within Groups	50.1501	27	1.857411			
Total	6427.077	29				

Anova: Single Factor
Phase Angle (P)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	110.2329	11.02329	0.372874
Frozen (12 hrs)	10	125.5312	12.55312	0.178892
Frozen (24 hrs)	10	72.98227	7.298227	0.160319

HSD	0.540154
Fresh - Frozen (12hrs)	-1.52983
Fresh - Frozen (24 hrs)	3.725068
Frozen (12hrs) - Frozen (24hrs)	5.254898

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	146.1015	2	73.05077	307.7614	2.612E-19	3.354131
Within Groups	6.408766	27	0.237362			
Total	152.5103	29				

Scallop 36

Anova: Single Factor
Resistance (R)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2218.97	221.897	22.49158
Frozen (12 hrs)	10	2127.67	212.767	2.524157
Frozen (24 hrs)	10	1292.66	129.266	3.368316

HSD	3.410268
Fresh - Frozen (12hrs)	9.13
Fresh - Frozen (24 hrs)	92.631
Frozen (12hrs) - Frozen (24hrs)	83.501

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	52120.92	2	26060.46	2754.412	6.172E-32	3.354131
Within Groups	255.4565	27	9.46135			
Total	52376.38	29				

Anova: Single Factor
Imedance (Z)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2256.108	225.6108	20.93399
Frozen (12 hrs)	10	2178.564	217.8564	2.990014
Frozen (24 hrs)	10	1302.606	130.2606	3.737001

HSD	3.366552
Fresh - Frozen (12hrs)	7.75439
Fresh - Frozen (24 hrs)	95.3502
Frozen (12hrs) - Frozen (24hrs)	87.59581

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	56082.73	2	28041.36	3041.252	1.631E-32	3.354131
Within Groups	248.9491	27	9.220335			
Total	56331.68	29				

Anova: Single Factor
Reactance (X)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	407.45	40.745	0.455361
Frozen (12 hrs)	10	467.98	46.798	2.219351
Frozen (24 hrs)	10	160.46	16.046	1.098804

HSD	1.243439
Fresh - Frozen (12hrs)	-6.053
Fresh - Frozen (24 hrs)	24.699
Frozen (12hrs) - Frozen (24hrs)	30.752

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	5307.883	2	2653.942	2109.922	2.211E-30	3.354131
Within Groups	33.96165	27	1.257839			
Total	5341.845	29				

Anova: Single Factor
Phase Angle (P)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	104.1176	10.41176	0.126619
Frozen (12 hrs)	10	124.0454	12.40454	0.12088
Frozen (24 hrs)	10	70.72543	7.072543	0.141265

HSD	0.399112
Fresh - Frozen (12hrs)	-1.99278
Fresh - Frozen (24 hrs)	3.33922
Frozen (12hrs) - Frozen (24hrs)	5.331997

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	145.1725	2	72.58624	560.1306	1.042E-22	3.354131
Within Groups	3.498878	27	0.129588			
Total	148.6714	29				

Scallop 37

Anova: Single Factor
Resistance (R)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2491.07	249.107	37.78998
Frozen (12 hrs)	10	2197.46	219.746	196.1141
Frozen (24 hrs)	10	1336.35	133.635	47.38669

HSD	10.73567
Fresh - Frozen (12hrs)	29.361
Fresh - Frozen (24 hrs)	115.472
Frozen (12hrs) - Frozen (24hrs)	86.111

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	72036.52	2	36018.26	384.139	1.467E-20	3.354131
Within Groups	2531.617	27	93.7636			
Total	74568.14	29				

Anova: Single Factor
Imedance (Z)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2511.131	251.1131	34.3036
Frozen (12 hrs)	10	2237.885	223.7885	192.081
Frozen (24 hrs)	10	1342.927	134.2927	46.74232

HSD	10.57873
Fresh - Frozen (12hrs)	27.32453
Fresh - Frozen (24 hrs)	116.8204
Frozen (12hrs) - Frozen (24hrs)	89.49586

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	74677.14	2	37338.57	410.1232	6.241E-21	3.354131
Within Groups	2458.142	27	91.04231			
Total	77135.28	29				

Anova: Single Factor
Reactance (X)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	315.16	31.516	7.863093
Frozen (12 hrs)	10	422.77	42.277	2.252557
Frozen (24 hrs)	10	132.45	13.245	0.221361

HSD	2.058016
Fresh - Frozen (12hrs)	-10.761
Fresh - Frozen (24 hrs)	18.271
Frozen (12hrs) - Frozen (24hrs)	29.032

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4308.285	2	2154.143	625.1737	2.445E-23	3.354131
Within Groups	93.0331	27	3.44567			
Total	4401.318	29				

Anova: Single Factor
Phase Angle (P)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	72.23846	7.223846	0.585008
Frozen (12 hrs)	10	109.2002	10.92002	0.389591
Frozen (24 hrs)	10	56.76011	5.676011	0.149776

HSD	0.678745
Fresh - Frozen (12hrs)	-3.69617
Fresh - Frozen (24 hrs)	1.547835
Frozen (12hrs) - Frozen (24hrs)	5.244009

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	145.1904	2	72.59522	193.6949	9.736E-17	3.354131
Within Groups	10.11937	27	0.374792			
Total	155.3098	29				

Scallop 38

Anova: Single Factor
Resistance (R)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2559.07	255.907	0.98709
Frozen (12 hrs)	10	2105.45	210.545	43.80803
Frozen (24 hrs)	10	1547.17	154.717	11.62882

HSD	4.808205
Fresh - Frozen (12hrs)	45.362
Fresh - Frozen (24 hrs)	101.19
Frozen (12hrs) - Frozen (24hrs)	55.828

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	51379.64	2	25689.82	1365.9	7.476E-28	3.354131
Within Groups	507.8155	27	18.80798			
Total	51887.46	29				

Anova: Single Factor
Imedance (Z)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2605.472	260.5472	0.859752
Frozen (12 hrs)	10	2146.108	214.6108	42.82726
Frozen (24 hrs)	10	1558.415	155.8415	11.25802

HSD	4.744773
Fresh - Frozen (12hrs)	45.9364
Fresh - Frozen (24 hrs)	104.7057
Frozen (12hrs) - Frozen (24hrs)	58.76932

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	55090.91	2	27545.46	1503.983	2.062E-28	3.354131
Within Groups	494.5052	27	18.31501			
Total	55585.42	29				

Anova: Single Factor
Reactance (X)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	489.36	48.936	1.791493
Frozen (12 hrs)	10	415.65	41.565	0.083806
Frozen (24 hrs)	10	186.75	18.675	0.147806

HSD	0.910459
Fresh - Frozen (12hrs)	7.371
Fresh - Frozen (24 hrs)	30.261
Frozen (12hrs) - Frozen (24hrs)	22.89

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4980.04	2	2490.02	3692.375	1.201E-33	3.354131
Within Groups	18.20794	27	0.674368			
Total	4998.247	29				

Anova: Single Factor
Phase Angle (P)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	108.2671	10.82671	0.09283
Frozen (12 hrs)	10	111.7556	11.17556	0.07106
Frozen (24 hrs)	10	68.87739	6.887739	0.068747

HSD	0.308739
Fresh - Frozen (12hrs)	-0.34885
Fresh - Frozen (24 hrs)	3.938973
Frozen (12hrs) - Frozen (24hrs)	4.287824

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	113.4088	2	56.7044	731.238	3.072E-24	3.354131
Within Groups	2.093735	27	0.077546			
Total	115.5025	29				

Scallop 39

Anova: Single Factor
Resistance (R)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2515.18	251.518	31.94877
Frozen (12 hrs)	10	2339.67	233.967	46.24971
Frozen (24 hrs)	10	1757.36	175.736	45.21438

HSD	7.111014
Fresh - Frozen (12hrs)	17.551
Fresh - Frozen (24 hrs)	75.782
Frozen (12hrs) - Frozen (24hrs)	58.231

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	31472.66	2	15736.33	382.5289	1.55E-20	3.354131
Within Groups	1110.716	27	41.13762			
Total	32583.38	29				

Anova: Single Factor
Imedance (Z)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2547.395	254.7395	27.5978
Frozen (12 hrs)	10	2378.188	237.8188	44.14005
Frozen (24 hrs)	10	1776.876	177.6876	44.81383

HSD	6.910517
Fresh - Frozen (12hrs)	16.92072
Fresh - Frozen (24 hrs)	77.05196
Frozen (12hrs) - Frozen (24hrs)	60.13124

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	32796.94	2	16398.47	422.0909	4.285E-21	3.354131
Within Groups	1048.965	27	38.85056			
Total	33845.9	29				

Anova: Single Factor
Reactance (X)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	402.84	40.284	4.670004
Frozen (12 hrs)	10	426.04	42.604	0.252938
Frozen (24 hrs)	10	262.37	26.237	1.097401

HSD	1.570587
Fresh - Frozen (12hrs)	-2.32
Fresh - Frozen (24 hrs)	14.047
Frozen (12hrs) - Frozen (24hrs)	16.367

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1568.598	2	784.2988	390.8243	1.171E-20	3.354131
Within Groups	54.18309	27	2.006781			
Total	1622.781	29				

Anova: Single Factor
Phase Angle (P)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	91.12445	9.112445	0.453057
Frozen (12 hrs)	10	103.2975	10.32975	0.134602
Frozen (24 hrs)	10	84.99713	8.499713	0.151655

HSD	0.550384
Fresh - Frozen (12hrs)	-1.21731
Fresh - Frozen (24 hrs)	0.612732
Frozen (12hrs) - Frozen (24hrs)	1.830039

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	17.3544	2	8.677199	35.21049	2.996E-08	3.354131
Within Groups	6.653824	27	0.246438			
Total	24.00822	29				

Scallop 40

Anova: Single Factor
Resistance (R)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2335.03	233.503	7.513623
Frozen (12 hrs)	10	2152.66	215.266	57.2092
Frozen (24 hrs)	10	1355.25	135.525	19.33736

HSD	5.868762
Fresh - Frozen (12hrs)	18.237
Fresh - Frozen (24 hrs)	97.978
Frozen (12hrs) - Frozen (24hrs)	79.741

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	54303.01	2	27151.51	969.0023	7.295E-26	3.354131
Within Groups	756.5417	27	28.02006			
Total	55059.55	29				

Anova: Single Factor
Reactance (X)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	332.47	33.247	5.189357
Frozen (12 hrs)	10	406.28	40.628	0.130484
Frozen (24 hrs)	10	133.05	13.305	0.62825

HSD	1.561134
Fresh - Frozen (12hrs)	-7.381
Fresh - Frozen (24 hrs)	19.942
Frozen (12hrs) - Frozen (24hrs)	27.323

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	3995.696	2	1997.848	1007.642	4.334E-26	3.354131
Within Groups	53.53282	27	1.982697			
Total	4049.229	29				

Anova: Single Factor
Imedance (Z)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2358.703	235.8703	6.282065
Frozen (12 hrs)	10	2190.692	219.0692	55.96842
Frozen (24 hrs)	10	1361.794	136.1794	19.084

HSD	5.772829
Fresh - Frozen (12hrs)	16.80108
Fresh - Frozen (24 hrs)	99.69084
Frozen (12hrs) - Frozen (24hrs)	82.88976

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	56970.84	2	28485.42	1050.677	2.482E-26	3.354131
Within Groups	732.0104	27	27.1115			
Total	57702.85	29				

Anova: Single Factor
Phase Angle (P)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	81.08244	8.108244	0.376707
Frozen (12 hrs)	10	106.976	10.6976	0.08769
Frozen (24 hrs)	10	56.13478	5.613478	0.154491

HSD	0.503567
Fresh - Frozen (12hrs)	-2.58936
Fresh - Frozen (24 hrs)	2.494767
Frozen (12hrs) - Frozen (24hrs)	5.084124

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	129.2565	2	64.62826	313.2792	2.075E-19	3.354131
Within Groups	5.569993	27	0.206296			
Total	134.8265	29				

Scallop 41

Anova: Single Factor
Resistance (R)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2621.96	262.196	23.83736
Frozen (12 hrs)	10	2005.07	200.507	8.001757
Frozen (24 hrs)	10	1294.76	129.476	17.72674

HSD	4.506533
Fresh - Frozen (12hrs)	61.689
Fresh - Frozen (24 hrs)	132.72
Frozen (12hrs) - Frozen (24hrs)	71.031

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	88218.45	2	44109.22	2669.734	9.389E-32	3.354131
Within Groups	446.0927	27	16.52195			
Total	88664.54	29				

Anova: Single Factor
Reactance (X)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	562.93	56.293	4.180468
Frozen (12 hrs)	10	424.75	42.475	0.615806
Frozen (24 hrs)	10	129.38	12.938	0.114418

HSD	1.418478
Fresh - Frozen (12hrs)	13.818
Fresh - Frozen (24 hrs)	43.355
Frozen (12hrs) - Frozen (24hrs)	29.537

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	9810.092	2	4905.046	2996.551	1.99E-32	3.354131
Within Groups	44.19622	27	1.636897			
Total	9854.288	29				

Anova: Single Factor
Imedance (Z)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2681.859	268.1859	19.0649
Frozen (12 hrs)	10	2049.593	204.9593	7.364306
Frozen (24 hrs)	10	1301.226	130.1226	17.33012

HSD	4.234348
Fresh - Frozen (12hrs)	63.22666
Fresh - Frozen (24 hrs)	138.0634
Frozen (12hrs) - Frozen (24hrs)	74.83671

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	95532.12	2	47766.06	3274.689	6.034E-33	3.354131
Within Groups	393.8339	27	14.58644			
Total	95925.95	29				

Anova: Single Factor
Phase Angle (P)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	121.2742	12.12742	0.404483
Frozen (12 hrs)	10	119.6423	11.96423	0.096197
Frozen (24 hrs)	10	57.15474	5.715474	0.09662

HSD	0.494706
Fresh - Frozen (12hrs)	0.163189
Fresh - Frozen (24 hrs)	6.41195
Frozen (12hrs) - Frozen (24hrs)	6.248761

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	267.2891	2	133.6446	671.2432	9.547E-24	3.354131
Within Groups	5.375701	27	0.1991			
Total	272.6648	29				

Scallop 42

Anova: Single Factor
Resistance (R)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	3289.19	328.919	8.063166
Frozen (12 hrs)	10	2122.45	212.245	41.47203
Frozen (24 hrs)	10	1415.27	141.527	0.515223

HSD	4.528508
Fresh - Frozen (12hrs)	116.674
Fresh - Frozen (24 hrs)	187.392
Frozen (12hrs) - Frozen (24hrs)	70.718

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	179098.7	2	89549.37	5367.55	7.813E-36	3.354131
Within Groups	450.4538	27	16.68347			
Total	179549.2	29				

Anova: Single Factor
Reactance (X)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	786.26	78.626	2.349071
Frozen (12 hrs)	10	355.15	35.515	3.18625
Frozen (24 hrs)	10	139.35	13.935	0.554472

HSD	1.57962
Fresh - Frozen (12hrs)	43.111
Fresh - Frozen (24 hrs)	64.691
Frozen (12hrs) - Frozen (24hrs)	21.58

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	21697.27	2	10848.63	5344.336	8.282E-36	3.354131
Within Groups	54.80814	27	2.029931			
Total	21752.08	29				

Anova: Single Factor
Imedance (Z)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	3381.917	338.1917	6.120783
Frozen (12 hrs)	10	2152.104	215.2104	37.71885
Frozen (24 hrs)	10	1422.129	142.2129	0.599857

HSD	4.26713
Fresh - Frozen (12hrs)	122.9813
Fresh - Frozen (24 hrs)	195.9788
Frozen (12hrs) - Frozen (24hrs)	72.9975

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	196202.5	2	98101.24	6622.571	4.61E-37	3.354131
Within Groups	399.9554	27	14.81316			
Total	196602.4	29				

Anova: Single Factor
Phase Angle (P)
SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	134.4695	13.44695	0.122599
Frozen (12 hrs)	10	95.16229	9.516229	0.464417
Frozen (24 hrs)	10	56.22594	5.622594	0.076824

HSD	0.521534
Fresh - Frozen (12hrs)	3.930722
Fresh - Frozen (24 hrs)	7.824358
Frozen (12hrs) - Frozen (24hrs)	3.893636

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	306.1052	2	153.0526	691.6696	6.42E-24	3.354131
Within Groups	5.974557	27	0.22128			
Total	312.0797	29				

Scallop 43

Anova: Single Factor

Resistance (R)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2709.47	270.947	75.2258
Frozen (12 hrs)	10	1754.36	175.436	50.25172
Frozen (24 hrs)	10	1074.47	107.447	8.461801

HSD	7.408074
Fresh - Frozen (12hrs)	95.511
Fresh - Frozen (24 hrs)	163.5
Frozen (12hrs) - Frozen (24hrs)	67.989

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	134923.7	2	67461.84	1511.024	1.937E-28	3.354131
Within Groups	1205.454	27	44.64644			
Total	136129.1	29				

Anova: Single Factor

Imedance (Z)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2797.309	279.7309	66.5315
Frozen (12 hrs)	10	1787.527	178.7527	49.93603
Frozen (24 hrs)	10	1078.052	107.8052	8.235988

HSD	7.1481
Fresh - Frozen (12hrs)	100.9782
Fresh - Frozen (24 hrs)	171.9257
Frozen (12hrs) - Frozen (24hrs)	70.94746

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	149295.3	2	74647.64	1795.803	1.919E-29	3.354131
Within Groups	1122.332	27	41.56784			
Total	150417.6	29				

Anova: Single Factor

Reactance (X)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	694.86	69.486	1.078493
Frozen (12 hrs)	10	342.66	34.266	0.317427
Frozen (24 hrs)	10	87.59	8.759	0.20281

HSD	0.809355
Fresh - Frozen (12hrs)	35.22
Fresh - Frozen (24 hrs)	60.727
Frozen (12hrs) - Frozen (24hrs)	25.507

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	18596.08	2	9298.04	17447.67	9.807E-43	3.354131
Within Groups	14.38857	27	0.53291			
Total	18610.47	29				

Anova: Single Factor

Phase Angle (P)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	144.0155	14.40155	0.403818
Frozen (12 hrs)	10	110.6148	11.06148	0.062391
Frozen (24 hrs)	10	46.68417	4.668417	0.117305

HSD	0.488964
Fresh - Frozen (12hrs)	3.340069
Fresh - Frozen (24 hrs)	9.733132
Frozen (12hrs) - Frozen (24hrs)	6.393063

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	489.2039	2	244.602	1257.565	2.255E-27	3.354131
Within Groups	5.251618	27	0.194504			
Total	494.4555	29				

Scallop 44

Anova: Single Factor

Resistance (R)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2752.63	275.263	46.05345
Frozen (12 hrs)	10	2181.84	218.184	66.404
Frozen (24 hrs)	10	1581.36	158.136	13.06238

HSD	7.171458
Fresh - Frozen (12hrs)	57.079
Fresh - Frozen (24 hrs)	117.127
Frozen (12hrs) - Frozen (24hrs)	60.048

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	68608.36	2	34304.18	819.8907	6.731E-25	3.354131
Within Groups	1129.678	27	41.83994			
Total	69738.04	29				

Anova: Single Factor

Imedance (Z)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2810.308	281.0308	32.60938
Frozen (12 hrs)	10	2232.163	223.2163	64.38123
Frozen (24 hrs)	10	1590.355	159.0355	12.31292

HSD	6.692192
Fresh - Frozen (12hrs)	57.8145
Fresh - Frozen (24 hrs)	121.9953
Frozen (12hrs) - Frozen (24hrs)	64.18084

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	74481.86	2	37240.93	1022.133	3.583E-26	3.354131
Within Groups	983.7318	27	36.43451			
Total	75465.59	29				

Anova: Single Factor

Reactance (X)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	563.36	56.336	25.2666
Frozen (12 hrs)	10	471.1	47.11	0.092111
Frozen (24 hrs)	10	168.47	16.847	0.871801

HSD	3.278345
Fresh - Frozen (12hrs)	9.226
Fresh - Frozen (24 hrs)	39.489
Frozen (12hrs) - Frozen (24hrs)	30.263

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	8534.498	2	4267.249	488.0478	6.387E-22	3.354131
Within Groups	236.0747	27	8.743506			
Total	8770.573	29				

Anova: Single Factor

Phase Angle (P)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	115.8998	11.58998	1.585853
Frozen (12 hrs)	10	121.9685	12.19685	0.133858
Frozen (24 hrs)	10	60.90048	6.090048	0.206612

HSD	0.888415
Fresh - Frozen (12hrs)	-0.60686
Fresh - Frozen (24 hrs)	5.499937
Frozen (12hrs) - Frozen (24hrs)	6.106799

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	226.3686	2	113.1843	176.2699	3.187E-16	3.354131
Within Groups	17.33691	27	0.642108			
Total	243.7055	29				

Scallop 45

Anova: Single Factor

Resistance (R)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	3303.27	330.327	55.50322
Frozen (12 hrs)	10	2360.83	236.083	53.14976
Frozen (24 hrs)	10	1514.66	151.466	3.251204

HSD	6.771337
Fresh - Frozen (12hrs)	94.244
Fresh - Frozen (24 hrs)	178.861
Frozen (12hrs) - Frozen (24hrs)	84.617

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	160110.8	2	80055.38	2146.176	1.759E-30	3.354131
Within Groups	1007.138	27	37.30139			
Total	161117.9	29				

Anova: Single Factor

Imedance (Z)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	3367.192	336.7192	47.11487
Frozen (12 hrs)	10	2399.488	239.9488	48.35377
Frozen (24 hrs)	10	1520.797	152.0797	2.924587

HSD	6.349418
Fresh - Frozen (12hrs)	96.77045
Fresh - Frozen (24 hrs)	184.6395
Frozen (12hrs) - Frozen (24hrs)	87.86904

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	170590.8	2	85295.38	2600.648	1.335E-31	3.354131
Within Groups	885.5391	27	32.79774			
Total	171476.3	29				

Anova: Single Factor

Reactance (X)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	652.04	65.204	5.317827
Frozen (12 hrs)	10	428.17	42.817	2.901712
Frozen (24 hrs)	10	135.87	13.587	1.545401

HSD	2.000258
Fresh - Frozen (12hrs)	22.387
Fresh - Frozen (24 hrs)	51.617
Frozen (12hrs) - Frozen (24hrs)	29.23

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	13399.62	2	6699.809	2058.326	3.081E-30	3.354131
Within Groups	87.88446	27	3.25498			
Total	13487.5	29				

Anova: Single Factor

Phase Angle (P)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	111.7852	11.17852	0.398937
Frozen (12 hrs)	10	102.9596	10.29596	0.417355
Frozen (24 hrs)	10	51.30679	5.130679	0.263036

HSD	0.66501
Fresh - Frozen (12hrs)	0.882553
Fresh - Frozen (24 hrs)	6.047839
Frozen (12hrs) - Frozen (24hrs)	5.165286

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	213.4515	2	106.7257	296.6451	4.201E-19	3.354131
Within Groups	9.713947	27	0.359776			
Total	223.1654	29				

Scallop 46

Anova: Single Factor

Resistance (R)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2385.85	238.585	20.26292
Frozen (12 hrs)	10	2524.97	252.497	4.422246
Frozen (24 hrs)	10	1549.04	154.904	19.67827

HSD	4.263476
Fresh - Frozen (12hrs)	-13.912
Fresh - Frozen (24 hrs)	83.681
Frozen (12hrs) - Frozen (24hrs)	97.593

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	55734.82	2	27867.41	1884.485	1.006E-29	3.354131
Within Groups	399.2709	27	14.78781			
Total	56134.09	29				

Anova: Single Factor

Imedance (Z)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2416.862	241.6862	18.44671
Frozen (12 hrs)	10	2591.692	259.1692	4.560402
Frozen (24 hrs)	10	1556.975	155.6975	19.0062

HSD	4.149013
Fresh - Frozen (12hrs)	-17.483
Fresh - Frozen (24 hrs)	85.98869
Frozen (12hrs) - Frozen (24hrs)	103.4717

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	61353.65	2	30676.82	2190.507	1.337E-30	3.354131
Within Groups	378.1198	27	14.00444			
Total	61731.77	29				

Anova: Single Factor

Reactance (X)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	385.59	38.559	1.10881
Frozen (12 hrs)	10	584.28	58.428	0.256707
Frozen (24 hrs)	10	156.66	15.666	0.493427

HSD	0.872739
Fresh - Frozen (12hrs)	-19.869
Fresh - Frozen (24 hrs)	22.893
Frozen (12hrs) - Frozen (24hrs)	42.762

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	9158.184	2	4579.092	7389.831	1.053E-37	3.354131
Within Groups	16.73049	27	0.619648			
Total	9174.915	29				

Anova: Single Factor

Phase Angle (P)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	91.87375	9.187375	0.16192
Frozen (12 hrs)	10	130.3008	13.03008	0.005785
Frozen (24 hrs)	10	57.84427	5.784427	0.151077

HSD	0.361409
Fresh - Frozen (12hrs)	-3.84271
Fresh - Frozen (24 hrs)	3.402948
Frozen (12hrs) - Frozen (24hrs)	7.245654

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	262.8198	2	131.4099	1236.674	2.821E-27	3.354131
Within Groups	2.869041	27	0.106261			
Total	265.6889	29				

Scallop 47

Anova: Single Factor

Resistance (R)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2410.73	241.073	28.85682
Frozen (12 hrs)	10	2317.87	231.787	31.38118
Frozen (24 hrs)	10	1327.05	132.705	6.059361

HSD	5.21194
Fresh - Frozen (12hrs)	9.286
Fresh - Frozen (24 hrs)	108.368
Frozen (12hrs) - Frozen (24hrs)	99.082

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	72156.99	2	36078.49	1632.576	6.878E-29	3.354131
Within Groups	596.6763	27	22.09912			
Total	72753.66	29				

Anova: Single Factor

Imedance (Z)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2466.156	246.6156	27.09594
Frozen (12 hrs)	10	2377.668	237.7668	30.72968
Frozen (24 hrs)	10	1334.407	133.4407	5.9552

HSD	5.112064
Fresh - Frozen (12hrs)	8.84878
Fresh - Frozen (24 hrs)	113.1749
Frozen (12hrs) - Frozen (24hrs)	104.3261

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	79236.02	2	39618.01	1863.476	1.169E-29	3.354131
Within Groups	574.0273	27	21.26027			
Total	79810.05	29				

Anova: Single Factor

Reactance (X)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	519.58	51.958	2.03384
Frozen (12 hrs)	10	529.46	52.946	4.409471
Frozen (24 hrs)	10	139.87	13.987	0.066957

HSD	1.633243
Fresh - Frozen (12hrs)	-0.988
Fresh - Frozen (24 hrs)	37.971
Frozen (12hrs) - Frozen (24hrs)	38.959

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	9868.589	2	4934.294	2273.775	8.104E-31	3.354131
Within Groups	58.59241	27	2.170089			
Total	9927.181	29				

Anova: Single Factor

Phase Angle (P)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	121.6943	12.16943	0.198454
Frozen (12 hrs)	10	128.7204	12.87204	0.294347
Frozen (24 hrs)	10	60.19505	6.019505	0.031214

HSD	0.463365
Fresh - Frozen (12hrs)	-0.70262
Fresh - Frozen (24 hrs)	6.149923
Frozen (12hrs) - Frozen (24hrs)	6.85254

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	284.2417	2	142.1209	813.6465	7.45E-25	3.354131
Within Groups	4.716131	27	0.174672			
Total	288.9579	29				

Scallop 48

Anova: Single Factor

Resistance (R)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2820.85	282.085	17.91136
Frozen (12 hrs)	10	2473.56	247.356	14.28056
Frozen (24 hrs)	10	1531.96	153.196	14.82536

HSD	4.389146
Fresh - Frozen (12hrs)	34.729
Fresh - Frozen (24 hrs)	128.889
Frozen (12hrs) - Frozen (24hrs)	94.16

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	88948.61	2	44474.31	2837.742	4.136E-32	3.354131
Within Groups	423.1555	27	15.67243			
Total	89371.77	29				

Anova: Single Factor

Imedance (Z)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2892.387	289.2387	15.70129
Frozen (12 hrs)	10	2517.989	251.7989	13.33313
Frozen (24 hrs)	10	1539.249	153.9249	14.21444

HSD	4.209579
Fresh - Frozen (12hrs)	37.43977
Fresh - Frozen (24 hrs)	135.3138
Frozen (12hrs) - Frozen (24hrs)	97.87402

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	97636.27	2	48818.14	3386.318	3.845E-33	3.354131
Within Groups	389.2398	27	14.41629			
Total	98025.51	29				

Anova: Single Factor

Reactance (X)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	639.1	63.91	0.658778
Frozen (12 hrs)	10	470.66	47.066	1.82276
Frozen (24 hrs)	10	149.27	14.927	0.549001

HSD	1.114323
Fresh - Frozen (12hrs)	16.844
Fresh - Frozen (24 hrs)	48.983
Frozen (12hrs) - Frozen (24hrs)	32.139

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	12386.57	2	6193.283	6130.873	1.303E-36	3.354131
Within Groups	27.27485	27	1.01018			
Total	12413.84	29				

Anova: Single Factor

Phase Angle (P)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	127.7057	12.77057	0.112758
Frozen (12 hrs)	10	107.7703	10.77703	0.139977
Frozen (24 hrs)	10	55.74	5.574	0.157486

HSD	0.409978
Fresh - Frozen (12hrs)	1.99354
Fresh - Frozen (24 hrs)	7.196574
Frozen (12hrs) - Frozen (24hrs)	5.203034

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	276.1215	2	138.0607	1009.655	4.22E-26	3.354131
Within Groups	3.691992	27	0.13674			
Total	279.8135	29				

Scallop 49

Anova: Single Factor
Resistance (R)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	3201.38	320.138	69.37508
Frozen (12 hrs)	10	2394.34	239.434	81.50034
Frozen (24 hrs)	10	1376.48	137.648	15.84813

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	167253.8	2	83626.88	1504.77	2.048E-28	3.354131
Within Groups	1500.512	27	55.57452			
Total	168754.3	29				

HSD	8.265131
Fresh - Frozen (12hrs)	80.704
Fresh - Frozen (24 hrs)	182.49
Frozen (12hrs) - Frozen (24hrs)	101.786

Anova: Single Factor
Imedance (Z)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	3294.862	329.4862	58.27217
Frozen (12 hrs)	10	2434.481	243.4481	77.61635
Frozen (24 hrs)	10	1383.333	138.3333	15.67136

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	183303.7	2	91651.85	1814.171	1.674E-29	3.354131
Within Groups	1364.039	27	50.51996			
Total	184667.7	29				

HSD	7.880312
Fresh - Frozen (12hrs)	86.03806
Fresh - Frozen (24 hrs)	191.1529
Frozen (12hrs) - Frozen (24hrs)	105.1148

Anova: Single Factor
Reactance (X)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	778.36	77.836	4.872382
Frozen (12 hrs)	10	439.78	43.978	0.888596
Frozen (24 hrs)	10	137.44	13.744	0.083916

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	20560.81	2	10280.41	5276.609	9.834E-36	3.354131
Within Groups	52.60404	27	1.948298			
Total	20613.42	29				

HSD	1.547532
Fresh - Frozen (12hrs)	33.858
Fresh - Frozen (24 hrs)	64.092
Frozen (12hrs) - Frozen (24hrs)	30.234

Anova: Single Factor
Phase Angle (P)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	136.8021	13.68021	0.48089
Frozen (12 hrs)	10	104.2392	10.42392	0.25376
Frozen (24 hrs)	10	57.06904	5.706904	0.042722

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	321.424	2	160.712	620.2137	2.716E-23	3.354131
Within Groups	6.996338	27	0.259124			
Total	328.4204	29				

HSD	0.564372
Fresh - Frozen (12hrs)	3.256285
Fresh - Frozen (24 hrs)	7.973303
Frozen (12hrs) - Frozen (24hrs)	4.717018

Scallop 50

Anova: Single Factor
Resistance (R)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2850.46	285.046	12.28458
Frozen (12 hrs)	10	2261.55	226.155	44.17381
Frozen (24 hrs)	10	1440.46	144.046	8.189249

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	100303.5	2	50151.73	2327.312	5.93E-31	3.354131
Within Groups	581.8287	27	21.54921			
Total	100885.3	29				

HSD	5.146685
Fresh - Frozen (12hrs)	58.891
Fresh - Frozen (24 hrs)	141
Frozen (12hrs) - Frozen (24hrs)	82.109

Anova: Single Factor
Imedance (Z)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	2903.405	290.3405	9.14998
Frozen (12 hrs)	10	2302.298	230.2298	40.51209
Frozen (24 hrs)	10	1449.41	144.941	7.987827

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	106761.7	2	53380.86	2777.847	5.508E-32	3.354131
Within Groups	518.8491	27	19.21663			
Total	107280.6	29				

HSD	4.86016
Fresh - Frozen (12hrs)	60.11068
Fresh - Frozen (24 hrs)	145.3996
Frozen (12hrs) - Frozen (24hrs)	85.28888

Anova: Single Factor
Reactance (X)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	551.18	55.118	6.204773
Frozen (12 hrs)	10	430.76	43.076	0.956738
Frozen (24 hrs)	10	160.75	16.075	0.052472

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	7994.732	2	3997.366	1662.341	5.4E-29	3.354131
Within Groups	64.92585	27	2.404661			
Total	8059.658	29				

HSD	1.719249
Fresh - Frozen (12hrs)	12.042
Fresh - Frozen (24 hrs)	39.043
Frozen (12hrs) - Frozen (24hrs)	27.001

Anova: Single Factor
Phase Angle (P)

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	10	109.4991	10.94991	0.363563
Frozen (12 hrs)	10	107.9784	10.79784	0.278342
Frozen (24 hrs)	10	63.7139	6.37139	0.038534

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	135.2648	2	67.63242	298.1861	3.929E-19	3.354131
Within Groups	6.123944	27	0.226813			
Total	141.3888	29				

HSD	0.528014
Fresh - Frozen (12hrs)	0.152068
Fresh - Frozen (24 hrs)	4.57852
Frozen (12hrs) - Frozen (24hrs)	4.426452

Appendix 7: Normalized Effect of Freezing Testing Secondary ANOVAs

Anova: Single Factor
Resistance

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	300	2615.728	8.719095	7.013081
Frozen (12hrs)	300	2336.01	7.786699	3.445853
Frozen (24hrs)	300	1605.521	5.351735	1.986588

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1813.752	2	906.8761	218.603	4.62E-78	3.00576
Within Groups	3721.211	897	4.148507			
Total	5534.963	899				

HSD	0.39068266
Fresh - Frozen (12hrs)	0.93239533
Fresh - Frozen (24hrs)	3.3673596
Frozen (12hrs) - Frozen (24hrs)	2.43496427

Anova: Single Factor
Reactance

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	300	469.1398	1.563799	0.707667
Frozen (12hrs)	300	472.2421	1.57414	0.160714
Frozen (24hrs)	300	176.0339	0.58678	0.035302

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	192.9555	2	96.47774	320.282	1.1E-105	3.00576
Within Groups	270.2011	897	0.301228			
Total	463.1566	899				

HSD	0.10527507
Fresh - Frozen (12hrs)	-0.0103411
Fresh - Frozen (24hrs)	0.97701947
Frozen (12hrs) - Frozen (24hrs)	0.98736057

Anova: Single Factor
Impedance

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	300	2660.767	8.869222	7.525084
Frozen (12hrs)	300	2384.108	7.947028	3.561767
Frozen (24hrs)	300	1615.355	5.384517	2.014219

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1956.007	2	978.0034	223.952	1.29E-79	3.00576
Within Groups	3917.22	897	4.367024			
Total	5873.227	899				

HSD	0.40083994
Fresh - Frozen (12hrs)	0.92219356
Fresh - Frozen (24hrs)	3.48470451
Frozen (12hrs) - Frozen (24hrs)	2.56251095

Anova: Single Factor
Phase Angle

SUMMARY

Groups	Count	Sum	Average	Variance
Fresh	300	2871.079	9.570262	8.68993
Frozen (12hrs)	300	3447.654	11.49218	2.364695
Frozen (24hrs)	300	1869.407	6.231356	0.807811

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4251.833	2	2125.917	537.6425	3.4E-154	3.00576
Within Groups	3546.868	897	3.954145			
Total	7798.701	899				

HSD	0.38142093
Fresh - Frozen (12hrs)	-1.921918
Fresh - Frozen (24hrs)	3.33890586
Frozen (12hrs) - Frozen (24hrs)	5.2608241